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Isotopic analysis of dietary patterns in northern China from the Proto-Shang Period to the Qin Dynasty

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Isotopic analysis of dietary patterns in northern China from the Proto-Shang Period to the Qin Dynasty

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CHAPTER 6 Tracing the Locality of Prisoners and Workers at the Mausoleum of Qin Shi Huang: First Emperor of China (259-210 BC)

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CHAPTER 1 Aims and Objectives of this Thesis

1.1 Introduction

Over 30 years have passed since stable isotope ratio analysis was first used to investigate paleodiet in China (Cai and Qiu, 1984). Since this pioneering study, there has been uneven but significant progress in the application of isotopic techniques to investigate Chinese archaeological material. However, there are many time periods, regions and topics which have yet to be examined in detail with stable isotopes in China.

Most of the previously published isotopic research focused on the Neolithic period (e.g. Zhang et al., 2003; Pechenkina et al., 2005; Hu et al., 2008; Barton et al. 2009; Lanehart et al., 2011), and later periods such as the early Bronze/Iron Ages that pre-date the formation of the Chinese Empire during the Qin Dynasty (221-206 BC), have been neglected. This is unfortunate as these pre-Empire periods are highly important to understand the formation processes of the first “Chinese” states and society. In addition, despite historical texts and archaeological evidence for social stratification in ancient Chinese society, only a handful of small scale isotopic studies have attempted to examine this topic in the past (Ling et al., 2010; Zhang et al, 2012; Zhang et al, 2014; Wang et al., 2014). Further, isotopic studies that investigate animal husbandry patterns and human mobility are uncommon in China. Thus, there exist significant gaps in our understanding and knowledge of the human lifeways and social patterns in pre-Qin Dynasty archaeological sites in China. Here my thesis will address this lack of information about these periods and topics by using three large and important site studies, where questions related to: stable isotope ratio analysis and dietary patterns, social stratification, animal husbandry practices and human mobility can be investigated.

1.2 Study Sites and Research Questions Investigated in this Thesis

In this dissertation three different archaeological locations from the Yellow River Valleys of north China are isotopically investigated (Figure 1.1). Each of these sites represents a different period of Chinese archaeology, spanning the late Longshan (ca. 2000 BC), or the terminal Neolithic/Early Bronze Age, to the Qin Dynasty (221-206 BC). These sites were selected from

a practical standpoint (access was granted for sampling, which can be difficult to obtain in China) as well as to provide more information about the dietary practices and social stratification of these understudied populations and time periods.

1.2.1 The Nancheng site

The earliest site is that of Nancheng (Figure 1.1), located in Hebei Province, and attributed to the Proto-Shang Culture (2000-1600 BC) of the Shang people before they founded the Shang Dynasty (1600-1046 BC). While many archaeological sites dating to the Proto-Shang culture have been excavated over the last decades in Henan and southern Hebei Province, knowledge about the lifeways, diet and social stratification during this period remains limited. The archaeological evidence and historical sources suggest that this group practiced a varied subsistence strategy based upon hunting, animal husbandry and agriculture (Zhang, 2002; Chen, 2007; Zhu, 2007; Hou et al. 2009; 2013). However, little direct research has explored the diet and social complexity of the Proto-Shang people, and only a single isotopic study has been previously published on a Proto-Shang archaeological site (Hou et al. 2013). This earlier work at the site of Liuzhuang found that the human diet was based on millets, pigs, cattle and dogs, and no differences related to age, sex or burial type (pit, stone coffin, and wooden coffin) were found. However, this research was limited in scope as only a small number of individuals were analyzed (n=21).

In chapter 4 of my thesis, I analyze the stable isotope ratios of carbon ($\delta^{13}\text{C}$), nitrogen ($\delta^{15}\text{N}$) and sulfur ($\delta^{34}\text{S}$) of bone collagen from humans (n=83) at the Nancheng site and animals from the nearby (~3 km) and contemporaneous site of Baicun (Table 1.1). The findings of this work were published in the *American Journal of Physical Anthropology*, and the full citation is listed below:

Ma Y., Fuller B.T., Wei D., Shi L., Zhang X., Hu Y., Richards M.P. 2016. Isotopic perspectives ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$, $\delta^{34}\text{S}$) of diet, social complexity, and animal husbandry during the Proto-Shang period (ca. 2000 – 1600 BC) of China. *American Journal of Physical Anthropology* 160, 433-445.

The main goals of this research are as follows:

1. Reconstruct the subsistence patterns and animal husbandry practices of this site to determine if the type of animal protein consumed was mainly centered on certain species of domestic animals such as pigs and cattle (as found by Hou et al. 2013), as opposed to other domestic animals (sheep/goats) and wild animals.
2. Investigate if there are unique dietary patterns that are linked to sex, age, and burial direction/position in the population.
3. Examine if dietary differences are linked to perceived social status, as inferred from the type of grave goods interred with the deceased. The goal of this type of analysis is to provide information about possible social hierarchy in a pre-state level society in China that was transitioning from an egalitarian to a hierarchical society.

1.2.2 The Xishan site

The second site investigated in this thesis is Xishan, which is located in eastern Gansu Province (Figure 1.1), and dates to the Late Western Zhou to Warring States Periods (ca. 700-400 BC). It is a typical Qin culture site, the ancestors of those that established the Qin Dynasty, and was believed to have had a well-developed and rigid social structure (Sun, 2009). As the Qin can be viewed as the founders of Imperial China, a large volume of research has been devoted to their early history, culture and formation as a society (Duan, 1982; Ma, 1982; Xu, 2003). Past research has yielded conflicting results in terms of the subsistence strategies (nomadic pastoral vs. agriculture) of the early Qin, and this is an area of active debate (Zhang, 2001; Wang, 2007). Only a single small scale study that combined isotopic results and dental health patterns has been previously published for the Xishan site (Wei, 2008; Wei et al., 2009), but as no animal results were analyzed to act as a baseline to the human isotopic values, this study was limited in its ability to determine the type of animal protein consumed at the site. Thus, the dietary practices of the early Qin have yet to be fully investigated and resolved.

In chapter 5 of my thesis, I analyzed bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from humans (n=33) and animals (n=58) excavated at the Xishan site (Table 1.1). The findings of this work were published in the *International Journal of Osteoarchaeology*, and the full citation is listed below:

Ma Y., Fuller B.T., Chen L., Zhao C., Hu Y., Richards MP. 2016. Reconstructing diet of the Early Qin (ca. 700-400 BC) at Xishan, Gansu Province, China. *International Journal of Osteoarchaeology* 26, 959-973.

The central research questions of this work include:

1. Determine the human subsistence and animal husbandry practices at the Xishan site to see if they were engaged in nomadic pastoral activities, agriculture or a mixture of both practices.
2. Investigate if diets were different as a result of the well-defined social status (based on the number and quality of grave goods) during this period.
3. Examine if there were differences between tomb owners and sacrificial victims to again investigate differences related to social status.
4. Determine if there were dietary differences related to sex (males vs. females) which can also be related to social status since the early Qin were a male dominated society.

1.2.3 The Qin Shi Huang Mausoleum

The last site that is investigated is from the world famous Qin Shi Huang Mausoleum (Terra Cotta Warriors), located near the modern city of Xi'an in Shaanxi Province (Figure 1.1). Here two separate and contemporary archaeological sites associated with the Qin Shi Huang Mausoleum complex were investigated. The first is the public cemetery of Liyi, which was a city built specifically as a supply base for the construction of the Qin Shi Huang Mausoleum. The second is the Shanren site, which is a mass grave containing the bodies of workers and/or slaves that died during the construction of the Qin Shi Huang Mausoleum (SPIA and EQTWHM, 2007). It is believed that over 700,000 individuals from all over China were used to build the mausoleum complex during the 39 years of its construction (Sima, 1961; Li, 1975; Yuan, 1986). However, the identities and origins of these workers and/or conscripts have not been fully elucidated. In recent years, this has become an important focus of archaeological investigation with scholars in China studying grave goods, inscriptions and mtDNA to gain a better understanding of these individuals (Zhang, 2001; Xu, 2008).

In chapter 6 of my thesis, I analyzed bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from humans (n=223) and animals (n=9) from the Liyi site. In addition, I analyzed bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from humans (n=19) at the Shanren site (Table 1.1). The findings of this work were published in *Scientific Reports*, and the full citation is listed below:

Ma Y., Fuller B.T., Sun W., Hu S., Chen L., Hu Y., Richards M.P. Tracing the locality of prisoners and workers at the Mausoleum of Qin Shi Huang: First Emperor of China (259-210 BC) *Scientific Reports* 6, 26731 (DOI: 10.1038/srep26731)

The main research questions addressed here are:

1. Determine the dietary habits of the workers/craftsmen from the public cemetery of Liyi and the prisoners from the mass grave at Shanren that constructed the Qin Shi Huang Mausoleum for the first Emperor of China. Do dietary differences exist between these two populations and are these related to status or geography?
2. Review and examine the previously published isotopic studies of north (millet eating) and south (rice eating) China, and use these results to better understand the diets and possible geographic origins of these individuals found at Liyi and Shanren.

Table 1.1. Summary information about human and faunal bone samples used in this thesis.

<i>Site</i>	<i>Region</i>	<i>Culture</i>	<i>Period</i>	<i>Society</i>	<i>Humans</i>	<i>Fauna</i>
Nancheng	Southern Hebei Province	Pro-Shang	Late Longshan period	Primary hierarchy	83	36 (6 species)
Xishan	Eastern Gansu Province	Proto-Qin	Late Western Zhou to Warring States	Highly hierarchy (with human sacrifice)	33	58 (8 species)
Liyi	Central Shaanxi Province	Qin	Late Warring States to Qin Dynasty	Highly hierarchy	223	9 (7 species)
Shanren					19	

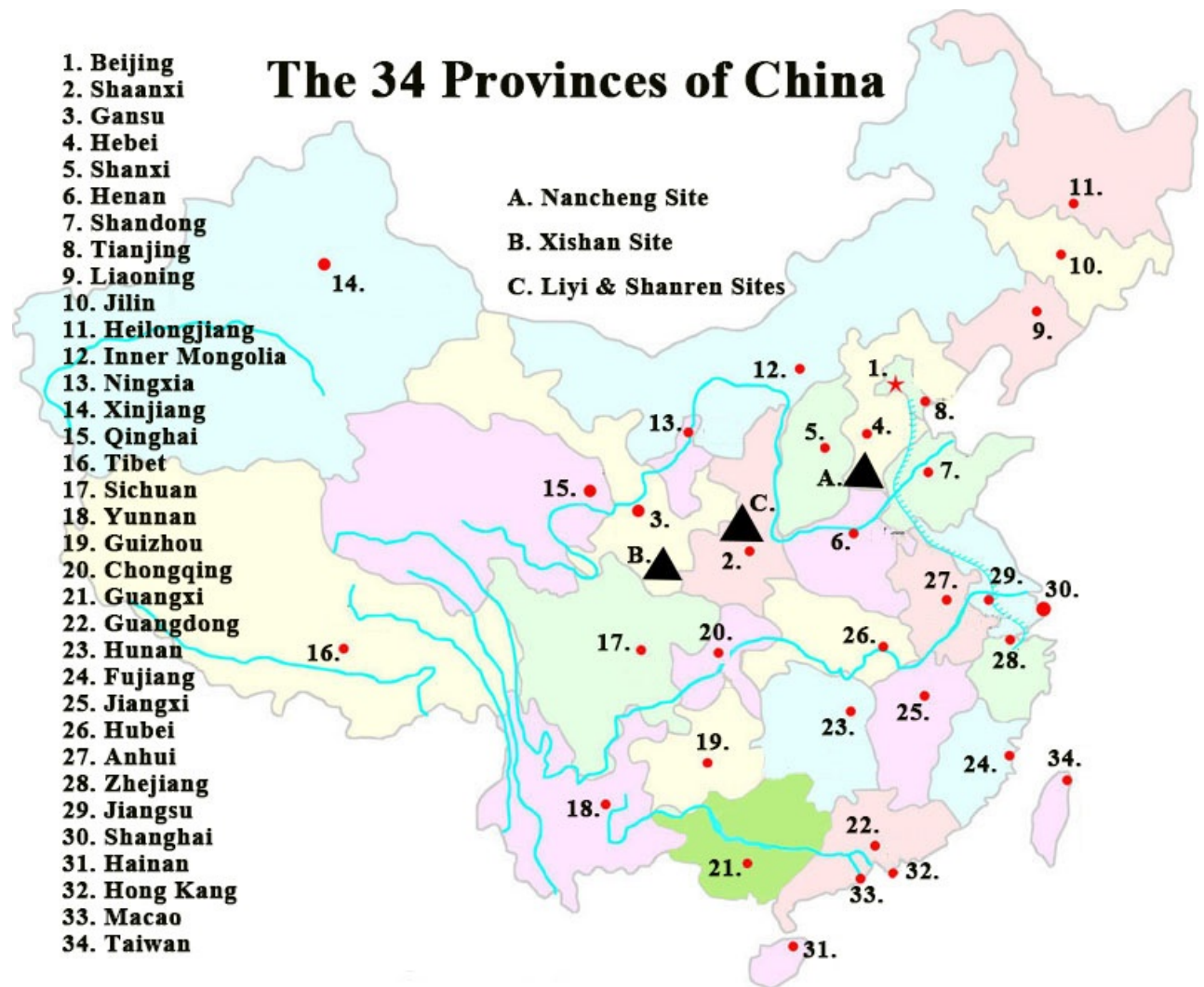


Figure 1.1. Map showing the 34 Provinces of China and the location of the three archaeological sites that are the focus of these thesis.

1.3 Structure of this Thesis

The structure of this thesis is as follows:

Chapter 1 – Introduction

Chapter 2 – Paleodiet Reconstruction and Stable Isotope Ratio Analysis

Chapter 3 – Introduction to the Cultural Prehistory and History of China

Chapter 4 – The Nancheng Site: published in the *American Journal of Physical Anthropology*

Chapter 5 – The Xishan Site: published in the *International Journal of Osteoarchaeology*

Chapter 6 – The Qin Shi Huang Mausoleum: published in *Scientific Reports*

Chapter 7 – Conclusions and Future Work

In chapter 2, I briefly summarize paleodietary studies, as well as, review stable isotope ratio analysis as this is the main investigative technique that is used in this thesis. Chapter 3 presents and overview of the cultural prehistory and history of China as this is a topic that may not be as familiar to western archeologists. Chapters 4-6 present the results of my thesis research as described above, and finally, in chapter 7, I summarize the key findings of my work and outline areas of future research.

CHAPTER 2 Paleodiet Reconstruction and Stable Isotope Ratio Analysis

2.1 Introduction

Eating is one of the most common, yet one of the most fundamental and vital activities of everyday life. The choice of foods consumed by an individual is a complex process that can be dependent on a variety of factors such as: traditions, religion, economics, social factors, gender, personal preferences and food availability (Coyston et al., 1999; Sutton and Yohe, 2007; Mays, 2010). The investigation of dietary habits in the past, known as paleodiet reconstruction (Kazenberg, 2000; Twiss, 2012; Reitsema, 2013; Price, 2015), can provide important information about an individual or a human population, well beyond that of: What did ancient people eat? Thus, there are a variety of different techniques that have been developed and applied to archaeological materials in order to investigate paleodiet practices. Here, I will briefly discuss some of these and then focus on stable isotope ratio analysis, as this is the analytical technique that is the focus of this thesis work.

2.1.1 Techniques for the investigation of paleodiet

Unfortunately, the actual remains of foodstuff are rarely found at most archaeological sites around the world. However, in cases where foods are recovered, this information can yield exceptional insights into the dietary habits of the past. For example, at the late Neolithic (c. 4000 BP) site of Lajia in Qinghai Province, millet noodles were found well preserved in an overturned bowl (Figure 2.1) (Lv et al., 2005). This site is commonly referred to as the Pompeii of China, since a large earthquake destroyed the dwellings and quickly entombed individuals and their everyday possessions. Thus, Lajia provides a unique and unprecedented view of the life and activities of individuals in northwest China during the late Neolithic period. In addition, to the actual remains of dietary items, written records and historical sources as well as art (if these items survive) can supply detailed and potentially accurate information about the types of foods consumed, cooking techniques and agricultural practices in the past. For example, in China the book *Yin Shan Zheng Yao* (饮膳正要), dating to the 14th century AD during the Yuan Dynasty lists abundant recipes for the preparation of meat and noodle dishes for elite individuals (Hu, 2010). However, many archaeological sites do not contain these sorts of information, so other means of investigation are required to understand the culinary habits of

our ancestors, and these are briefly summarized below.



Figure 2.1. A picture of 4000-year-old millet noodles from the site of Lajia in Qinghai Province, China (from Lv et al., 2005).

2.1.2 Archaeobotany

Archaeobotany (or paleoethnobotany) is defined as “the analysis and interpretation of archaeobotanical remains to provide information on the interactions of human populations and plants” (Hastorf, 1999). Archaeobotany was first carried out in Europe by botanists in the 1950’s at archaeological sites in Switzerland (Wright, 2010). Since this time, this discipline has greatly expanded to include a host of different methods for the recovery and identification of archaeological plant remains (Hastorf and Popper, 1989; Pearsall, 2009). Macro-plant remains, such as cereal grains, seeds and chaff are identified by morphological characteristics such as size, shape and surface features. This type of analysis provides valuable information for examining questions related to hunter-gather economies and the origins of agriculture and domestication (Gremillion, 1997; Pennington and Weber, 2010). Micro-plant remains such as starch grains, phytoliths and pollen can also be recovered and identified to the species level (Warnock, 1998; Harvey and Fuller, 2005). In addition to paleodietary information, this type

of analysis is important for the reconstruction of past climates and environmental conditions (Piperno, 2006; Pearsall and Hastorf, 2011). For example, Lv et al. (2016) extracted phytoliths and biomolecular compounds such as caffeine from ancient plant remains from two funerary sites in China: the Han Yangling Mausoleum in Xi'an (Shaanxi Province) and the Gurgyam cemetery in the Ngari District of Tibet. They found that tea was grown 2100 years ago to cater to the drinking habits of individuals of the Western Han Dynasty (207 BC-9 AD), and then carried to Central Asia by ca. 200 AD along a branch of the Silk Road, several hundred years earlier than previously thought. In another example, Jiang et al. (2006) analyzed plant remains which were found in a leather basket and wooden bowl for a tomb of a male shaman at the Yanghai cemetery, Turpan District in Xinjiang and dating to 500 BC (Figure 2.2). By comparing the morphological and anatomical characteristics with modern samples, they were able to identify the plant remains as *Cannabis sativa* and believe that this plant was used for ritual or medicinal purposes.

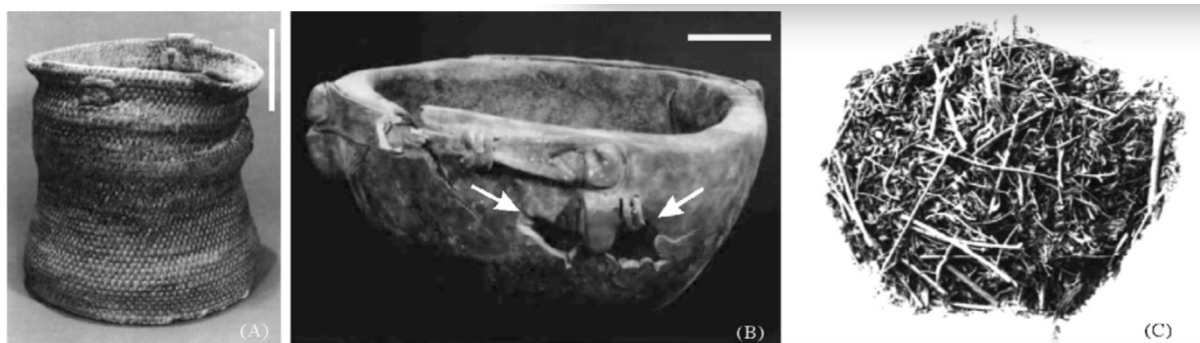


Figure 2.2. A) Leather basket B) Wooden bowl C) *Cannabis sativa* from the Yanghai cemetery, Xinjiang. (from Jiang et al. 2006).

2.1.3 Zooarchaeology

Zooarchaeology involves the study of animal remains from archaeological sites, to understand all aspects of past human and animal interactions (Reitz and Wing, 2008; Broderick, 2016). In most cases the remains primarily consist of the hard parts of the body such as bones and teeth, but where available, research has also been focused on hair, hides, horns and shells (O'Connor, 2004). Zooarchaeology became a sub-discipline of archaeology after World War II, and is now commonly employed at most archaeological excavations (Thomas, 1996). Techniques regularly used by zooarchaeologists involve the identification and quantification of the type of species, taphonomy (the study of the burial processes that influence bones), isotopic analysis,

DNA analysis, etc. (Peres, 2010; Albarella et al., 2016). These studies permit investigations into complex questions relating to human and animal relationships such as past hunting activities, subsistence practices, economics and paleoenvironments (Lyman, 1996; O'Day et al., 2003; Defrance, 2009). For example, Li et al. (2014) analyzed sheep and goats remains from two terminal Neolithic sites, Taosi and Xinzhai (ca. 2500-1800 BC), as well as one Early Bronze Age site Erlitou (ca. 1800-1500 BC) in Shanxi and Henan Provinces. This research revealed the complexity of sheep and goat herding practices in the Central Plains of China, and explored the use of secondary production products such as, wool and milk, by the inhabitants of these sites. In particular, the results indicate that at Erlitou, sheep were mainly exploited for meat consumption during phases II and III, but were mainly exploited for wool production during phase IV of the occupation. This work also found evidence that there were different sheep/goat usage patterns between elite and non-elite social groups as well as between urban vs. village sites.

2.1.4 Residue analysis

Residue analysis involves the isolation and identification of chemical components or biomarkers found on archaeological objects, and this technique has been used on a host of diverse materials such as bone, stone, metal and soils (Pecci, 2014). Analysis of organic residues from archaeological artifacts can provide important information about what an object was used for, as well as, the type of materials found in vessels such as cups or pots (Evershed, 1993; 2008). This type of analysis consists of techniques such as: infrared spectroscopy, Raman spectroscopy, nuclear magnetic resonance (NMR) and various forms of gas chromatography/mass spectrometry (GC/MS) (Evershed et al., 1990; Eerkens, and Barnard, 2007; Baeten, 2012). For example, in China, this method has been used to directly identify the presence of rice, honey or grape in a mixed fermented beverage from early Neolithic pottery jars at the site of Jiahu in Henan Province (McGovern et al., 2004). In addition, a recent study by Wang et al. (2016) examined pottery vessels from the Yangshao site of Mijiaya (3400-2900 BC) in Shaanxi Province (Figure 2.3). They found that the organic residues were a match for a beer recipe where broomcorn millet (*Panicum miliaceum*), barley (*Hordeum vulgare*), Job's tears (*Coix lacrymajobi*) and tubers were fermented together. This indicates that people in ancient China established advanced beer brewing technology by using specialized tools to create favorable fermentation conditions over 5,000 years ago.



Figure 2.3. Pottery vessel with beer residues from the Mijiaya site, Shaanxi Province (from Wang et al. 2016).

2.2 Introduction to Stable Isotope Ratio Analysis

Developed in the 1970s as an offshoot of radiocarbon dating (Makarewicz and Sealy, 2015), stable isotope ratio analysis can be summarized by the common phrase: “You are what you eat”. Basically, the isotopic signatures of the foods and liquids consumed by an organism are incorporated into its tissues in a relatively known and predictable manner (Lee-Thorp, 2008). Therefore, the measurement of these isotopic signatures allows an approximate reconstruction of dietary habits in the past. This technique has become a common addition to archaeological studies in the last 25 years and has been used to investigate a variety of research topics such as: subsistence practices, animal husbandry patterns, health and nutrition, social status, etc. (Kazenber, 2000; Lee-Thorp, 2008; Schoeninger, 2011; Reitsema and Vercellotti, 2012; Reitsema, 2013). What follows in this chapter is a brief overview of the technique of stable isotope ratio analysis.

2.2.1 Definitions

An isotope is defined as an atom with the same number of protons but with a different number of neutrons (Sharp, 2007) (Figure 2.4). Isotopes were first discovered in 1913 by the English

chemist, Sir Fredrick Soddy. The word “isotope” is derived from the Greek word *iso* (same or equal) and *topos* (place), and this is because isotopes of an element occupy the same position or place in the periodic table (Platzner, 2012). Isotopes can be divided into two types, stable and unstable (radioactive), and are commonly written using the following notation ${}^A\text{X}$, where X represents the chemical symbol of an element and A is the sum of the number of protons and neutrons. For example, three isotopes of carbon exist in nature:

${}^{12}\text{C}$ = Stable (6 protons + 6 neutrons = 12)

${}^{13}\text{C}$ = Stable (6 protons + 7 neutrons = 13)

${}^{14}\text{C}$ = Radioactive (6 protons + 8 neutrons = 14)

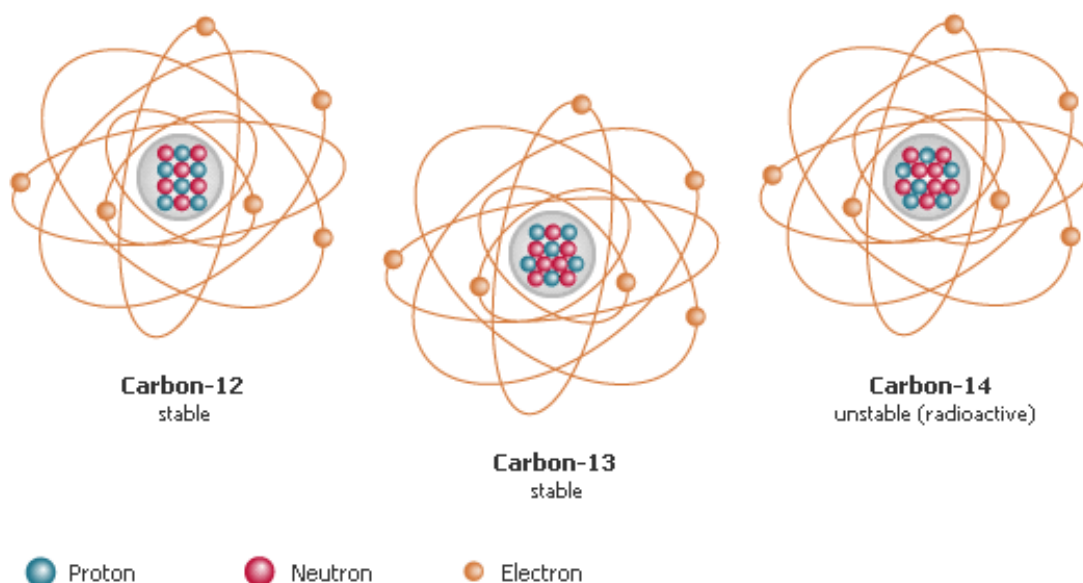


Figure 2.4. The three naturally occurring isotopes of carbon, each having the same numbers of electrons and protons but a different numbers of neutrons. (from <http://imgarcade.com/1/all-carbon-isotopes/>).

Most of the natural elements (66 out of 94) exist as mixtures of two or more isotopes, but the relative abundances of these different isotopes can vary substantially (Platzner, 2012). There are approximately 300 naturally occurring stable isotopes, and 1200 radioactive isotopes that have been discovered to date. Table 2.1 shows the stable isotopes of the common elements that

are studied in archaeology, but since this thesis is only focused on the measurement of carbon, nitrogen, and sulfur isotopes, only these will be discussed in detail (Fritz and Fontes, 1986; Fry, 2006).

Table 2.1. Stable isotopes of the common elements used paleodiet reconstruction (modified from Fritz and Fontes, 1986; Fry, 2006).

<i>Element</i>	<i>Isotopes</i>	<i>Nature Abundance (in percent)</i>	<i>Isotope Ratio Measured</i>
Hydrogen	¹ H	99.985	D/H
	² H or (D)	0.015	
Carbon	¹² C	98.89	¹³ C/ ¹² C
	¹³ C	1.11	
Nitrogen	¹⁴ N	99.64	¹⁵ N/ ¹⁴ N
	¹⁵ N	0.36	
Oxygen	¹⁶ O	99.76	¹⁸ O/ ¹⁶ O
	¹⁷ O	0.037	
	¹⁸ O	0.024	
Sulphur	³² S	95.02	³⁴ S/ ³² S
	³³ S	0.76	
	³⁴ S	4.21	
	³⁶ S	0.014	

2.2.2 Fractionation

While possessing the same chemical properties (e.g. ¹²C, ¹³C and ¹⁴C are all elements of carbon), the mass differences related to the variable number of neutrons can result in subtle yet detectable differences in the isotopes of an element. Fractionation is the term used to describe the partitioning of isotopes between two substances or two phases of the same substance (Schoeller, 1999). In general, the lighter elements (lower atomic masses) show more fractionation than the heavier elements since they tend to have chemical bonds that are more susceptible to breakage. There are two types of fractionations for isotopes: kinetic disequilibrium fractionation and thermodynamic equilibrium fractionation (Hayes, 1982). Kinetic fractionation is associated with incomplete and unidirectional processes, and this is the

main form of isotopic fractionation associated with biological systems in terms of enzymatic reactions (O’Leary, 1981). Thermodynamic fractionation is associated with physical reactions where no bonds are broken and examples include: evaporation, distillation or infrared absorption (White, 2015).

2.2.3 Notation

Because the variations between stable isotope ratios are very small, generally only a few tenths of a percent, it is common practice to express the isotopic composition of a substance as a delta “ δ ” value which represents the measured deviation of an isotopic ratio against a particular elemental standard (Table 2). The δ values are expressed in parts per thousand (‰) using the following notation:

$$\delta \text{ sample (‰)} = \left(\frac{R_{\text{sample}}}{R_{\text{st}}} - 1 \right) \times 1000$$

Where R = the isotope ratio of the heavier to the lighter element in a measured sample divided by the standard of that element. For example, the equation for the stable isotope ratios of carbon is as follows:

$$\delta^{13}\text{C} = \left[\frac{\left(\frac{^{13}\text{C}}{^{12}\text{C}} \right)_{\text{sample}}}{\left(\frac{^{13}\text{C}}{^{12}\text{C}} \right)_{\text{st}}} - 1 \right] \times 1000$$

The international reference standards for the five common elements used in paleodiet reconstruction are listed in Table 2.2. A positive δ value reflects samples that have more of the heavy isotope compared to the standard, whereas a negative δ value reflects samples that have more of the lighter isotope compared to the standard. For example, the majority materials have less ^{13}C than the VPDB standard, so nearly all $\delta^{13}\text{C}$ values encountered in archaeological specimens are negative.

Table 2.2. The international reference standards for the five common elements used in paleodiet reconstruction (from Hoefs, 2009).

<i>Element</i>	<i>International Standard</i>
Hydrogen	Vienna-Standard Mean Ocean Water (V-SMOW)
Carbon	Vienna-Pee Dee Belemnite (VPDB)
Nitrogen	Atmospheric Nitrogen (AIR)
Oxygen	Vienna-Standard Mean Ocean Water (V-SMOW)
Sulphur	Vienna-Canyon Diablo Meteorite Troilite (VCDT)

2.2.4 Mass spectrometry

The most effective method of measuring the stable isotope ratios of an element is with an isotope ratio mass spectrometer (IRMS). This machine is specifically designed to measure small differences in the mixtures of naturally occurring isotopes by the manipulation of external electric and magnetic fields (Figure 2.5) (Brand, 2002).

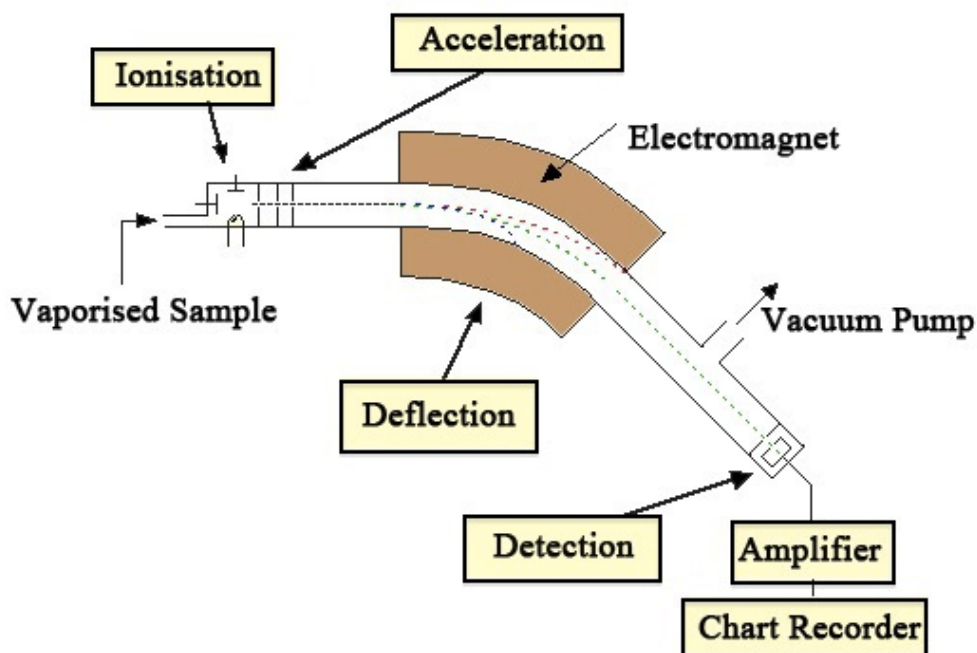


Figure 2.5. Schematic diagram showing a generic isotope ratio mass spectrometer (modified from Hoefs, 2009).

In paleodietary studies, solid substances such as bone/dentine collagen, hair, etc. are first placed in tin (for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analysis) or silver (for δD and $\delta^{18}\text{O}$) capsules. These capsules are then introduced into an elemental analyzer and combusted to create CO_2 and N_2 , and these gasses are carried to the ion source where they are transformed into electrically charged particles. The resulting ion beam is focused and directed into the mass analyzer via a flight tube. The mass analyzer contains electric and magnetic fields that are used to alter the speed and direction of the ions. The amount of deflection of the ion's trajectory depends on its mass-to-charge ratio (m/z) with lighter ions more easily deflected than heavier ions (Fry, 2006). When the beam of ions passes from the analyzer, it is measured in the ion detectors, and the abundances of each ion are calculated. For example, in Figure 2.6 a schematic diagram of a continuous flow IRMS is presented (Carter and Barwick, 2012).

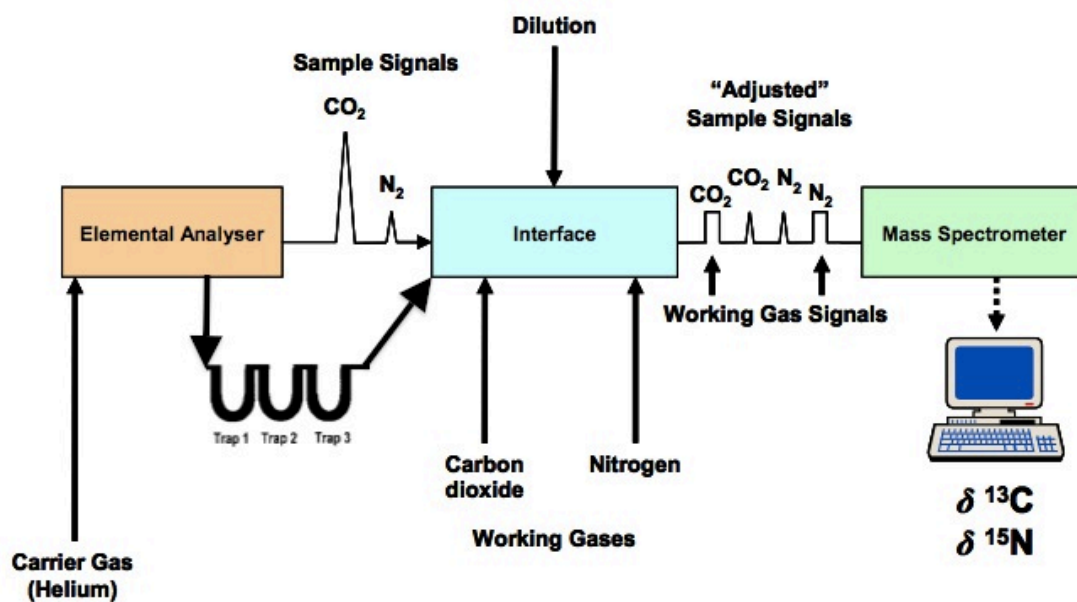


Figure 2.6. Simple schematic diagram of continuous flow isotope ratio mass spectrometry for the determination of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (modified from Carter and Barwick, 2012).

The four main components include: 1) Elemental analyzer – combusts or thermally converts a specimen into gas; 2) Interface – where the evolved gases are introduced into the mass spectrometer; 3) IRMS – separates and detects the ionized particles; 4) Calculation – quantification of the isotope results. In addition, laboratory standards must be also be analyzed for comparison with the unknown standards. In general, duplicate or triplicate measurements should be done for each sample (where possible) to increase the precision of the results (Faure

and Mensing, 2005).

2.3 Common Stable Isotope Ratios that are Studied in Paleodiet Research

2.3.1 Carbon ($\delta^{13}\text{C}$)

The two stable isotopes of carbon, ^{13}C and ^{12}C , have natural abundances of 1.1% and 98.9%, respectively (Burlingame and Schnoes, 1969). The majority of the carbon in the world is non-biological, but the largest sources of variability occurs during the transfer of atmospheric carbon to and from the ocean and into biological systems (Schoeninger and Moore, 1992). As a result of diffusion, the concentration of ^{12}C increases relative to ^{13}C , so that plants have negative $\delta^{13}\text{C}$ values compared with the source carbon (O'Leary, 1981). The $\delta^{13}\text{C}$ value of modern CO_2 is about -7‰. However, before the Industrial Revolution, this value was elevated by approximately 1.5‰. As a result of the release of anthropogenic carbon into the atmosphere from deforestation and the burning of fossil fuels (Suess effect), $\delta^{13}\text{C}$ values have become lower over the past few hundred years (Keeling, 1961; Bada et al., 1990). Thus, when we directly compare modern and archaeological $\delta^{13}\text{C}$ samples, 1.5‰ should to be added to the modern $\delta^{13}\text{C}$ values.

Atmospheric carbon dioxide (CO_2) is the main carbon source for all terrestrial plants. Land plants are divided into three types according to how they biosynthesize or fix carbon during photosynthesis. The three pathways of photosynthesis are: C_3 (Calvin-Benson Cycle), C_4 (Hatch-Slack Cycle) and CAM (Crassulean Acid Metabolism), and each of these pathways results in distinct $\delta^{13}\text{C}$ values in the tissues of plants (Park and Epstein, 1961; O'Leary, 1988). Plants are called C_3 , because the first product that they make during photosynthesis has a molecule with three carbon atoms (Schoeninger and Moore, 1992). The majority of the vegetation in temperate zones is composed of C_3 plants: trees, bushes, leafy plants and some grasses. The typical $\delta^{13}\text{C}$ values of C_3 plants range from -24‰ to -34‰ (with an average of -26.5‰) (Smith and Epstein, 1971). In contrast, C_4 plants produce a four-carbon compound during their first step of photosynthesis, hence their name. C_4 plants usually are native to hot and arid environments and include some important cultivated crops such as: maize, millet, sorghum and sugar cane (Price et al., 1985). The $\delta^{13}\text{C}$ results of C_4 plants are about 13‰ higher than C_3 plants, ranging from -16‰ to -9‰ (with an average of -12.5‰) (Smith and Epstein,

1971). Figure 2.7 shows the frequency and $\delta^{13}\text{C}$ values of C_3 and C_4 plants (from Cerling and Harris, 1999; Hoefs, 2009).

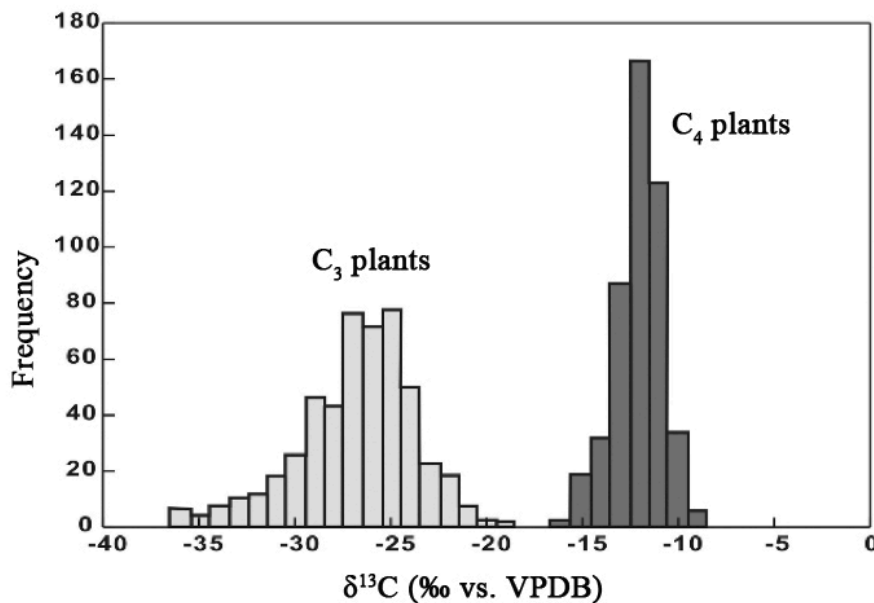


Figure 2.7. The frequency and $\delta^{13}\text{C}$ values of C_3 and C_4 plants (from Cerling and Harris, 1999; Hoefs, 2009).

CAM plants have more flexible means of photosynthesis and are able to switch between C_3 and C_4 pathways, depending on environmental conditions (Bender et al., 1973; Osmond, 1978). However, CAM plants are not the subject of frequent study in archaeology since few edible crops use this photosynthetic pathway (Price et al., 1985). Beside the principal influences of photosynthesis, some climatic effects can also lead to substantial variations in the $\delta^{13}\text{C}$ values of both C_3 and C_4 plants. These factors include but are not limited to: water and nutrient availability, temperature, altitude, light intensity and soil quality (Tieszen, 1991; van der Merwe and Medina, 1991; Lajtha and Marshall, 1994). For example, increased light and/or temperature and decreased water availability can result in an increase of the $\delta^{13}\text{C}$ values in plants of the same species (Heaton, 1999; Hedges et al., 2004).

In aquatic ecosystems, organisms can derive carbon from several sources, including terrestrial detritus (with $\delta^{13}\text{C}$ values representative of a mixture of local terrestrial plants), dissolved CO_2 (with $\delta^{13}\text{C}$ of atmospheric CO_2), and dissolved carbonic acid (with $\delta^{13}\text{C}$ values close to 0) (Schwarcz and Schoeninger, 1991). Therefore, the $\delta^{13}\text{C}$ values of aquatic plants can overlap with the values of terrestrial plants (Fry and Sherr, 1984). Marine organisms derive carbon

mainly from seawater, which is about 7-8‰ elevated in $\delta^{13}\text{C}$ values compare to atmospheric CO_2 (Craig, 1953; Richards and Hedges, 1999). Sea grasses have $\delta^{13}\text{C}$ values similar to C_4 plants, whereas some cold water plankton species have $\delta^{13}\text{C}$ values close to C_3 plants (see Figure 2.8).

The majority of marine species such as fish and higher carnivores such as seals and whales have ^{13}C -enriched values near -12‰ , and these values overlap with terrestrial C_4 consumers (Schwarcz and Schoeninger, 1991; Richards and Hedges, 1999). This can make the identification between the two groups difficult based on only $\delta^{13}\text{C}$ results. Freshwater plants and the fish that feed on them usually have mean $\delta^{13}\text{C}$ values near -25‰ , which is close to C_3 plants, but sometimes may vary widely, reflecting the contribution of various carbon sources (Rau, 1978; Chisholm et al., 1982; Schoeninger and DeNiro, 1984).

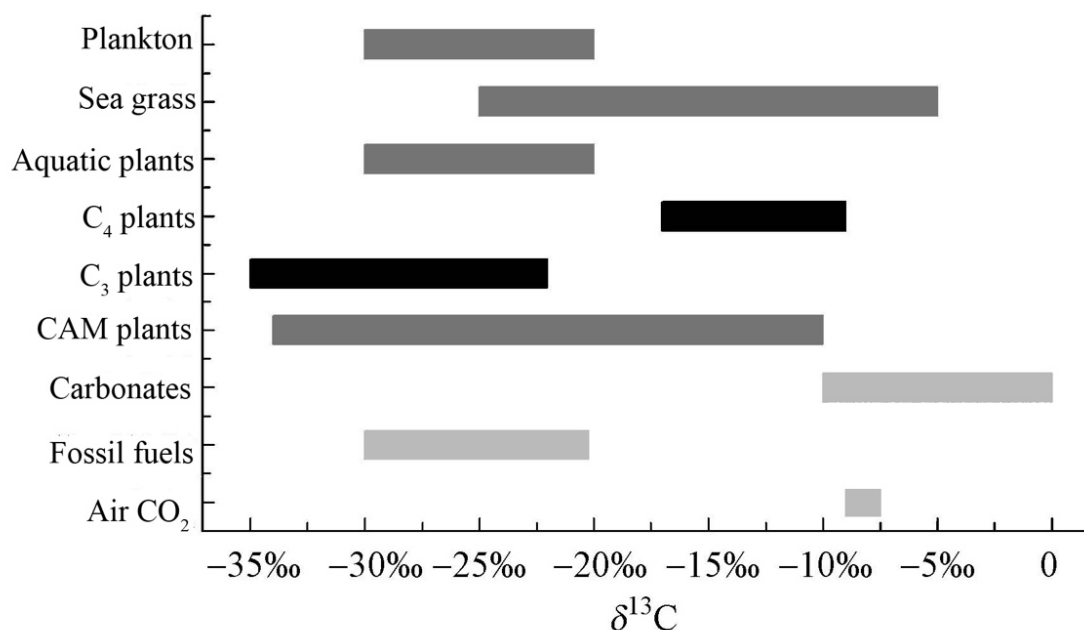


Figure 2.8. $\delta^{13}\text{C}$ values of different plants species (after Cerling and Harris, 1999).

The $\delta^{13}\text{C}$ difference between bulk diet and collagen, the carbon trophic level effect, is estimated to be 5‰ by a number of laboratory experiments (DeNiro and Epstein, 1978; van der Merwe and Vogel, 1978; Tieszen and Fagre, 1993). In addition, there is a trophic level effect of approximately 1‰ between the protein values of herbivores, omnivores and carnivores, and this has been observed in a number of studies (e.g. Bocherens and Drucker, 2003; McCutchan et al., 2003).

2.3.2 Nitrogen ($\delta^{15}\text{N}$)

The two stable isotopes of nitrogen, ^{15}N and ^{14}N , have abundances of 0.4% and 99.6%, respectively. More than 99% of the exchangeable nitrogen exists as either N_2 in the atmosphere or as dissolved N_2 in the ocean (White, 2015). Plants can uptake nitrogen from two different sources: the atmosphere or the soil. For example, some legumes (such as peas and beans) and algae (such as blue or green algae) can obtain nitrogen directly from the atmosphere. The $\delta^{15}\text{N}$ values of this fixed nitrogen in organic matter are generally similar to atmosphere N_2 (~0‰) (Michener and Lajtha, 2007). However, most plants are not able to directly uptake N_2 , and instead absorb nitrogen from the soil by assimilating NH_4^+ or NO_3^- . Thus, terrestrial plants using these nitrates display more positive $\delta^{15}\text{N}$ values than plants that use N_2 -fixing. Most modern non- N_2 -fixing plants have $\delta^{15}\text{N}$ values that generally range between 0‰ and 6‰, although a broad range is observed (Choi et al., 2003). The $\delta^{15}\text{N}$ values of terrestrial plants are strongly dependent on the soil, and other factors, such as: water availability, temperature, altitude, rainfall and the application of fertilizers (Ambrose, 1991; Schwarcz et al., 1999). Marine plants take up nitrogen from dissolved nitrates in the seawater, which are produced by bacterial denitrification, and these are more positive in ^{15}N compared with atmospheric and soil nitrogen. Thus, marine plants have higher $\delta^{15}\text{N}$ values than terrestrial plants (Wada, 1980). In addition, similar to marine systems, freshwater plants have high $\delta^{15}\text{N}$ values (France, 1995; Katzenberg and Weber, 1999).

The $\delta^{15}\text{N}$ values of animals and humans are related to their diets and increase by approximately 3-6‰ with each ascending step of the food chain, and this is known as the nitrogen trophic level effect (DeNiro and Epstein, 1981; Minagawa and Wada, 1984; Bocherens and Drucker, 2003; O'Connell et al., 2012). For example, in temperate environments, terrestrial herbivores have lower $\delta^{15}\text{N}$ values compared to carnivores, and in marine ecosystems lower trophic level fish have lower $\delta^{15}\text{N}$ values compared to higher trophic level fish and marine carnivores (Richards and Hedges, 1999; Lee-Throp, 2008) (Figure 2.9). Humans show distinct $\delta^{15}\text{N}$ differences related to diet with omnivores having higher $\delta^{15}\text{N}$ values compared to vegetarians and vegans (Petzke et al., 2005). Thus, the combination of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values is a valuable tool for distinguishing the types of food consumed from temperate C_3 and C_4 environments and from marine ecosystems.

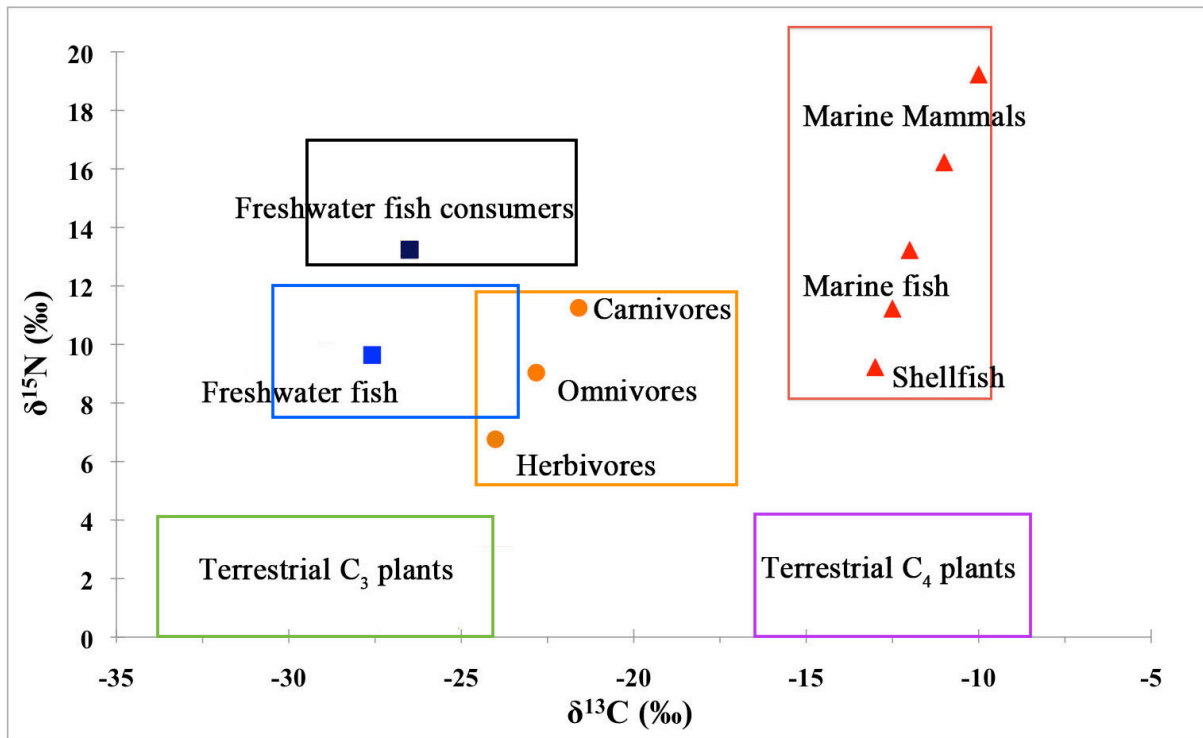


Figure 2.9. Simplified drawing of stable carbon and nitrogen isotope ratios in the biosphere. (Note: Black box = estimated range of freshwater fish consumers; Blue box = estimated range of freshwater fish; Green box = estimated range of terrestrial C₃ plants; Orange box = estimated range of C₃ terrestrial ecosystems; Red box = estimated range of marine ecosystems; Purple box = estimated range of terrestrial C₄ plants).

2.3.3 Sulphur ($\delta^{34}\text{S}$)

The four stable isotopes of sulphur and their natural abundances are listed: ³²S (95.02%), ³³S (0.76%), ³⁴S (4.21%), ³⁶S (0.014%). The isotopes that are commonly measured are ³²S and ³⁴S, since these are the two most abundant of the four (Hoefs, 2009). The $\delta^{34}\text{S}$ value is reported relative to the meteorite standard Vienna Canyon Diablo Troilite (VCDT) (Coplen and Krouse, 1998) by the standard equation:

$$\delta^{34}\text{S}_{\text{sample}} = \left[\frac{\left(\frac{^{34}\text{S}}{^{32}\text{S}} \right)_{\text{sample}}}{\left(\frac{^{34}\text{S}}{^{32}\text{S}} \right)_{\text{VCDT}}} - 1 \right] \times 1000$$

Sulphur is an important constituent of the lithosphere, biosphere, hydrosphere, and atmosphere.

The main reservoirs of sulphur are oceanic soluble sulphates, evaporitic sulphates, and reduced pyrites, with minor reservoirs found in the atmosphere, fossil fuels and the soil (Newton and Bottrell, 2007; Nehlich, 2015). The sulphur cycle has a number of similarities to the carbon cycle, through weathering, the water cycle and tectonic movements (Bottrell and Newton, 2006). Sulfur in marine environments is mainly present as sulphate (SO_4^{2-}), which is ^{34}S -enriched with a fairly uniform value of 20‰ across the global (Rees et al., 1978). Thus, marine organisms usually have $\delta^{34}\text{S}$ values near to 20‰. Sulphate in seawater can be transported by the wind and influence the $\delta^{34}\text{S}$ values of islands or coastal terrestrial regions, and this is known as the ‘sea spray effect’ (O’Dowd et al., 1997). The $\delta^{34}\text{S}$ values of freshwater environments have a wide range of variability, and this can be attributed to anaerobic bacteria in the sediments of rivers and lakes which can reduce the sulphate ions to hydrogen sulphide (Faure, 1997; Richards et al., 2003a). The $\delta^{34}\text{S}$ values for sedimentary rocks are highly variable depending on rock type and age (Faure, 1997). Terrestrial plants incorporate the majority of sulphur as sulphate (SO_4^{2-}) from the soil, and thus their $\delta^{34}\text{S}$ values generally reflect the geological $\delta^{34}\text{S}$ values. However, plants can also derive inorganic sulphur from the atmosphere (SO_2 , up to 90%) (Peterson and Fry, 1987; Richards et al., 2003a). Terrestrial plants have reported $\delta^{34}\text{S}$ values ranging from -22 to $+22$ ‰, and this high variability is a result of local environmental and geological conditions (Figure 2.10).

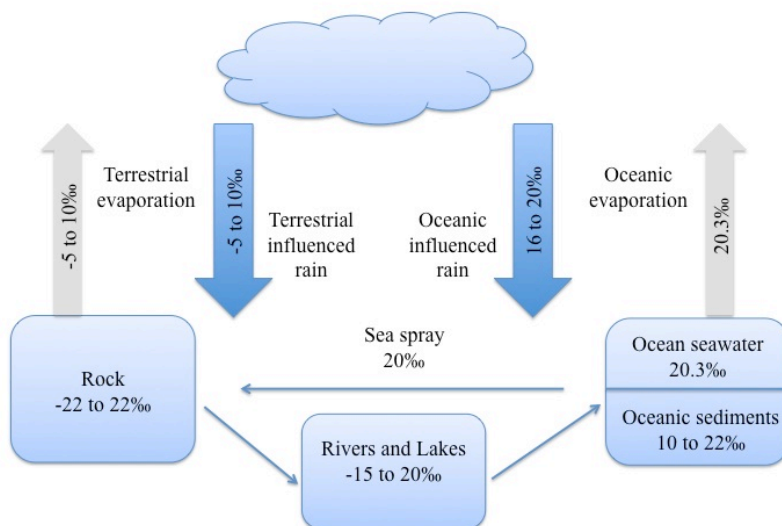


Figure 2.10. Box model of the sulphur cycle in the environment (modified from Nehlich, 2015).

Sulphur is an essential nutrient for animals and humans and is found in protein, various

vitamins and cofactors (Nielsen et al., 1991). There is only a slight fractionation (approximately -1‰) for $\delta^{34}\text{S}$ values with each step of the food chain or increase in trophic level (Richards et al., 2003a). Therefore, the $\delta^{34}\text{S}$ values in human and animal tissues generally reflect the $\delta^{34}\text{S}$ values of the food consumed (Hobson, 1999). Figure 2.11 shows the theoretical ranges for $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ values for specific food web niches and environments in archaeological research (Nehlich, 2015).

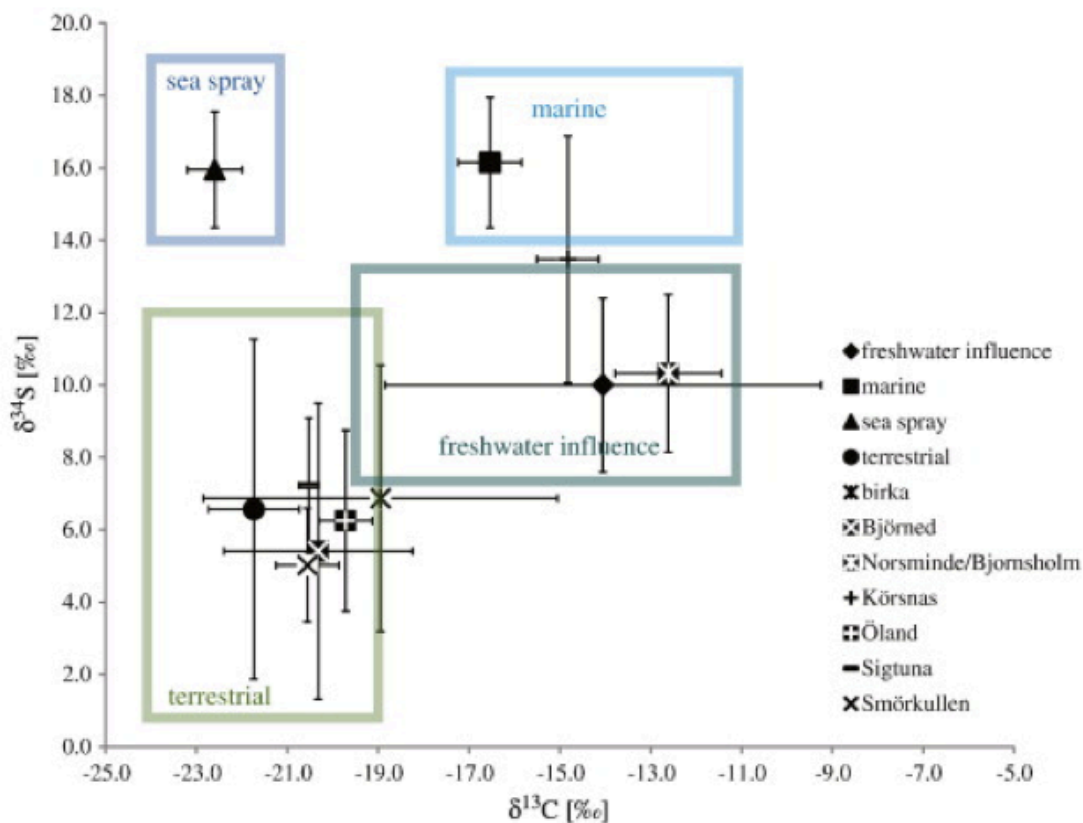


Figure 2.11. Theoretical ranges for $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ values for specific food web niches and environments in archaeological research (adapted from Nehlich, 2015).

With the improvements in continuous flow methods, smaller amounts of bone collagen (3-10 mg) can now be analyzed for $\delta^{34}\text{S}$ values, but this is still larger than what is required for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurements (Figure 2.12). Thus, combined with $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurements, the isotopic analysis of sulphur has become a more routine method applied to archaeological specimens.

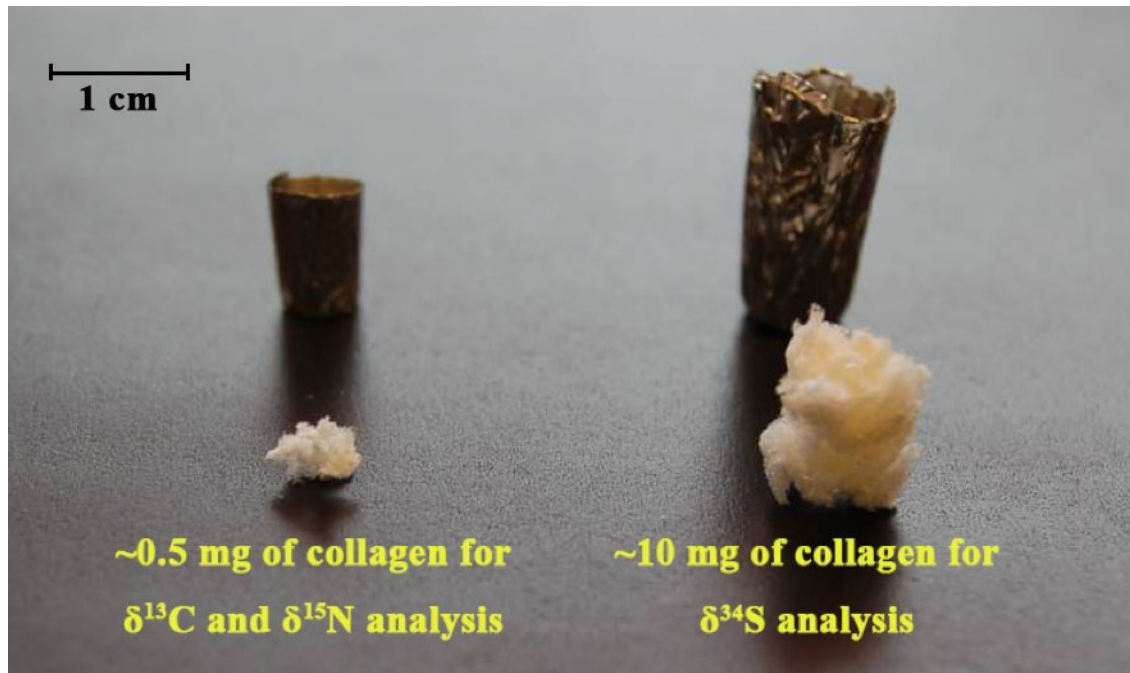


Figure 2.12. Differences in the amount of bone collagen needed for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ vs. $\delta^{34}\text{S}$ measurements.

2.4 Experimental Procedure of Stable Isotope Ratio Analysis

2.4.1 Common materials used for stable isotope analysis

The majority of paleodietary studies in archaeology are focused on bones and teeth for the simple reason that these are often the only tissues of an organism that survive the burial process (Mays, 2010). Bone is a complex tissue composed of an inorganic (mineral) fraction (approximately 55-75% of dry weight) and an organic matrix (White and Folkens, 2005). More than 90% of the organic component is the protein collagen, with the rest composed of other proteins such as osteocalcin (Masters, 1987; Bass, 2005). The mineral fraction in bone and tooth is mainly composed of calcium phosphate, which has the chemical formula $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$. Both collagen and bioapatite contain measurable amounts of carbon, which can be used to reconstruct dietary information. The bioapatite of carbon gives a measure of the whole diet, because bone mineral carbonate is dissolved in the blood, and thus reflects the total metabolic carbon pool which originates from dietary carbonate, lipid and protein (Katzenberg, 2000). However, collagen is mainly derived from dietary protein, and thus $\delta^{13}\text{C}$ collagen values mainly reflect ingested protein (Krueger and Sullivan, 1984; Ambrose and Norr, 1993; Tieszen

and Fagre, 1993). While the bone collagen turnover in an adult is rather slow, about 1.5-4% every year in cortical bone, the collagen turnover in children is much more rapid and is estimated to be between 10-30% in cortical bone per year (Hedges et al., 2007). Therefore, the collagen stable isotope data from adult bones reflect a person's average diet over the last decade or so of life.

Bone degrades over time after burial and collagen survival mainly depends on many factors including: temperature, soil moisture and pH and microbial attack (Smith et al., 2005; Mays, 2010). In certain special conditions such as cold or cave environments, collagen can survive for more than 100,000 years (e.g. Britton et al., 2012). Degraded collagen or collagen that is contaminated can result in altered isotopic compositions from the original value, and thus identifying the preservation of bone collagen is a priority for isotopic analysis. There are four main criteria that are routinely used to assess if $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from collagen are acceptable. These include: % collagen yield, %C, %N and atomic C:N (DeNiro, 1985; van Klinken, 1999). Of these four, the C:N is usually the most important and while a value of 3.2-3.3 is expected for modern collagen, values between 2.9-3.6 are considered acceptable for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurements (DeNiro, 1985). For $\delta^{34}\text{S}$ measurements, Nehlich and Richards (2009) designed quality criteria for archaeological bone samples. Measurements of samples with atomic C:S of 600 ± 300 and N:S of 200 ± 100 for mammalian collagen, and atomic C:S of 175 ± 50 and N:S ratio of 60 ± 20 for fish collagen are considered acceptable.

2.4.2 Collagen extraction

There have been several different methods developed to extract collagen from archaeological bones (see Longin, 1971; Schoeninger and DeNiro, 1984; Sealy, 1986; Brown et al., 1988; Tuross et al., 1989, Richards and Hedges, 1999). In this dissertation, collagen samples were prepared following the standard protocol detailed in Richards and Hedges (1999) with the addition of an ultrafiltration step as recommended by Brown et al. (1988) and Jørkov et al. (2007). Small bone chunks (approximately, 0.5-1.0 g) were cleaned by air abrasion with Al_2O_3 and then demineralized at 4 °C in a 0.5 M HCl solution for two weeks, with the acid changed every 2 days. Once demineralized, the samples were rinsed three times with deionized water, and then introduced to a pH=3 solution and gelatinized at 70 °C for 48 hours. The samples were first filtered with a 5 μm EZEE[®] filter to remove the insoluble residues; then the solution was

concentrated by Amicon[®] ultrafilters (<30kDa), and finally the purified collagen was frozen and freeze dried for 2 days.

2.5 Application of Stable Isotope Ratios in Archaeological Research

2.5.1 Subsistence practices

The earliest applications of stable isotopes to archaeological studies were mainly focused on maize agriculture in North America (Vogel and van der Merwe, 1977; van der Merwe and Vogel, 1978; Bender et al., 1981), and many subsequent studies on this topic were published (Schwarcz and Schoeninger, 1991; Schoeninger, 1995; Lee-Thorp, 2008). For example, it was found that maize replaced previously domesticated C₃ plants at different times in different regions. Near the Lake Erie area of Canada, maize became important to diets by about 500 AD (Stothers and Bechtel, 1987) whereas it was not until after 1000 AD that maize became important to human diets in southeastern Missouri, USA (Lynott et al., 1986). In contrast to North and South America, Europe does not have widespread C₄ agriculture, and the majority of edible plants are C₃ (Lee-Thorp, 2008). As a result of this, the first isotopic studies in Europe were focused on detecting marine vs. terrestrial diets. Tauber (1981) found that Danish Mesolithic individuals had a high proportion of marine foods in their diet, however, with the introduction of farming and domestic animals during the Neolithic period there was a dramatic shift away from marine foods toward these domestic foods. Similar isotopic patterns indicative of diets shifting from marine to terrestrial foods were also observed for the Mesolithic to Neolithic transitions in Portugal (Lubell et al., 1994) and Britain (Richards et al., 2003b).

In addition, to $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analysis, $\delta^{34}\text{S}$ measurements are increasingly applied to paleodiet studies to investigate aquatic vs. terrestrial resource consumption. For example, Nehlich et al. (2010) examined $\delta^{34}\text{S}$ values from humans and animals from five archaeological sites in Serbia along the Danube Gorges region dating from the Mesolithic to the middle Neolithic. The $\delta^{34}\text{S}$ values helped show clear evidence that both terrestrial and freshwater resources were exploited during the Mesolithic to the early Neolithic periods at these sites. However, during the later Neolithic period, fish and other aquatic foods were not consumed and diets were mainly composed of domestic animals.

2.5.2 Breastfeeding and weaning studies

An area of stable isotope analysis that has seen an increase in growth over the past 20 years is the reconstruction of breastfeeding and weaning patterns in modern and ancient humans (for a recent review see Tsutaya and Yoneda, 2015). This research is based on the fact that an infant becomes one trophic level higher than its mother during exclusive breastfeeding (e.g. Fogel et al., 1989; Fuller et al., 2006a). Thus, a 2-3‰ ^{15}N -enrichment in the tissues of an infant permits the tracking of the duration of breastfeeding, and with the weaning process or the introduction of solid food to the diet, the $\delta^{15}\text{N}$ values of an infant or child decrease due to the consumption of ^{15}N -depleted foods. At the point when a child becomes fully weaned their $\delta^{15}\text{N}$ results closely resemble maternal $\delta^{15}\text{N}$ values, assuming that both the mother and child consumed similar diets. In addition, $\delta^{13}\text{C}$ measurements also provide important information about breastfeeding and weaning patterns since a 1‰ increase is found between mothers and exclusively breastfed infants (Fuller et al., 2006a). The $\delta^{13}\text{C}$ values decline more rapidly to maternal levels during the weaning process, and this allows an estimation of the duration of exclusive breastfeeding. Thus, the combination of both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurements from the bones of children of different ages allows the reconstruction of breastfeeding and weaning patterns for an archaeological population. For example, Fuller et al. (2006b) conducted isotopic analysis on collagen from the Late/Sub-Roman site of Queenford Farm, UK. This study found that most children were fully weaned in a gradual process between the ages of 2-4 years old. In addition, lower $\delta^{13}\text{C}$ values suggest that children had a more plant based diet compared to the adult population. Isotopic analysis has also been done using tooth dentine and enamel to investigate individual patterns of breastfeeding and weaning (e.g. Fuller et al., 2003; Dupras and Tocheri, 2007). This type of research allows the investigation not only of infant/childhood diet but can be used to look at dietary patterns over the course of the age of formation of the tooth, and this has been applied with much success recently (Guiry et al., 2016). Unfortunately, there have been no isotopic applications of breastfeeding and weaning in China, but it is hoped that this type of research will be conducted in the future.

2.5.3 Hominid evolution

Isotopic studies have played an important role in the elucidation of hominid diets (e.g. Schoeninger, 1995; Lee-Thorp, 2008). For example, enamel $\delta^{13}\text{C}$ results show that

Australopithecus africanus, a ~3 million year old hominid from the Makapansgat Limeworks in South Africa, ate fruits, leaves and large amounts of ^{13}C -enriched foods, such as grasses and sedges or animals which ate these plants (Sponheimer and Lee-Thorp, 1999). In addition, this study found that these early hominids regularly exploited relatively open environments such as woodlands or grasslands for food. The results of this study suggest that *Australopithecus africanus* consumed high quality foods before the development of stone tools and the origin of the genus *Homo* (Sponheimer and Lee-Thorp, 1999). In Europe, isotopic studies on Neanderthals have discovered that they had similar diets through time (ca. 120000 - 37000 BP) and that they were top-level carnivores, obtaining almost all of their dietary protein from large herbivores (Richards et al., 2000; Richards and Trinkaus, 2009). In contrast, early modern humans in Europe (ca. 40000-27000 BP) had more variable diets compared to the Neanderthals. Specifically, some of the European early modern humans were consuming significant amounts of aquatic (marine and freshwater) foods (Richards and Trinkaus, 2009), and these dietary differences may have been one of the reasons that modern humans survived while Neanderthals went extinct.

CHAPTER 3 The Cultural Prehistory and History of China

3.1 A Brief Introduction to Chinese Prehistory and History

Modern China represents one of the earliest regions where civilization originated, and its culture and influence have had, and continue to have, an impact across the world (Schirokauer, 1991; Barnes, 1999; Loewe and Shaughnessy, 1999). Chinese civilization has its roots in different Neolithic cultures, and it has gradually developed in the context of warfare and territorial interactions until the formation of the Empire in 221 BC under the first Emperor Qin Shi Huang (Table 3.1) (Zhang et al., 2005; Yuan et al., 2012; Shelach-Lavi, 2015). Here I present a brief introduction to the chronology of Chinese prehistory and history that will be helpful for the understanding of the three publications that are discussed in chapters 4-6 of this thesis.

Table 3.1. A simplified historical sequence of China from the Neolithic to the Qin Dynasty.

10,000 BC	7,000 BC	5,000 BC	3,500 BC	2100 BC	1600 BC	1046 BC	771 BC	475 BC	221 BC
Early Neolithic	Middle Neolithic	Late Neolithic	Chalcolithic	Xia Dynasty ?	Shang Dynasty	Western Zhou	Spring and Autumn	Warring States	
Neolithic						Zhou Dynasty			
							Eastern Zhou		Qin Dynasty

3.2 Neolithic Culture

There were many different Neolithic cultures that existed across modern-day China, and these have been largely classified on the basis of their unique ceramic traditions (Figure 3.1) (Treistman, 1972; Zhang, 1986; Liu and Chen, 2012; Wilkinson, 2015). Most archaeologists have agreed to divide the Chinese Neolithic into four phases: Early, Middle, Late and Chalcolithic (Zhang, 2009; Ren and Wu, 2012), see Table 3.2.

Agriculture, pottery and stone polishing occurred both in north and south China at approximately the same time, around 10,000 BC (Ren and Wu, 2010). The most highly developed areas are found in the Yellow River Valleys of north China. While different regions produced their own separate and distinct cultures and chronologies, common elements coexist

as well, indicating that there was communication and exchange of ideas between these groups in northern China (Liu, 2004; Zhang and Wei, 2004). After 5000 BC various cultures flourished and became increasingly complex and finally transitioned to the Bronze Age by approximately 2000 BC (Dematte, 1999; Wang et al., 2007; Wang, 2013a; Liang, 2015).

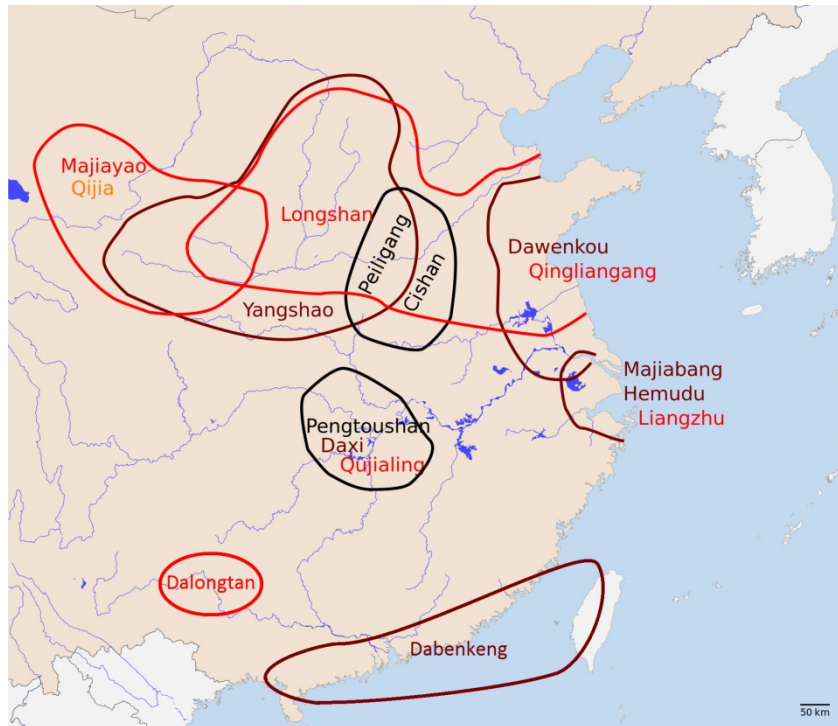


Figure 3.1. Map of the important Neolithic cultures of China and their territories (from https://commons.wikimedia.org/wiki/File:Neolithic_china.svg#/media/File:Neolithic_china.svg).

Table 3.2. Chronology and dating of the Chinese Neolithic.

Phase	Dating	Major Cultures	
		Northern China	Southern China
Early Neolithic	10000-7000 BC	Nanzhuangtou, Hutouliang	Yuchanyan
Middle Neolithic	7000-5000 BC	Cishan-Peiligang, laoguantai, Xinglongwa	Pengtoushan, Chengbeixi
Late Neolithic	5000-3500 BC	Yangshao, Dawenkou, Hongshan	Hemudu, Daxi
Chalcolithic	3500-2100 BC	Longshan	Liangzhu, Shijiahe

3.2.1 Yangshao culture (5000-3000 BC)

The Yangshao culture is the best documented and known of the Chinese Neolithic cultures (Gong, 2002). Its name comes from the village of Yangshao in Henan Province where the first remains of this culture were excavated and described by the Swedish archaeologist J.G. Andersson in 1921 (Zhang, 1986;). More than a thousand archaeological sites of the Yangshao culture have been found scattered over a large area including modern-day Henan, Shaanxi, Gansu and Qinghai Provinces (NBCR, 1991; 1999). The Yangshao culture is distinguished by its distinctive red and black painted pottery, which is decorated with human faces, animals and fish, geometrical designs, and markings that resemble an early form of writing (Figure 3.2) (Underhill, 2002; Qiu, 2013).

The Yangshao culture has been divided into three different phases and these as well as important characteristics of the culture are listed in Table 3 (Li, 2013; Liu and Chen, 2012; Zhu, 2013; Zhang, 2005). For example, the Banpo site in Shaanxi Province is representative of the early phase of the Yangshao culture. This large circular site was enclosed by a deep defensive ditch with a plaza in the center, and all of the doors of the houses faced the plaza. The inhabitants of Banpo interred their dead in a special burial area and babies were buried in pottery jars around the living areas of their houses (Xi'an Banpo Museum, 1982).



Figure 3.2. A) Typical pottery of the Yangshao culture from the Banpo site. B) Typical drawings of fish and deer from Banpo pottery. C) Close up of the human face and fish from the

bowl in A (photo from the Banpo Museum, Xi'an, China).

Table 3.3. Chronology, sites and characteristics of the Yangshao culture.

Phase	Dating	Examples of Major sites	Region	Social Organization
Early	5000-4000 BC	Banpo, Jiangzhai Beishouling Dadiwan	Wei River Valley in Shaanxi Province	Egalitarian
Middle	4000-3500 BC	Miaodigou Xipo	Expanded in all directions from the above	Development of social hierarchy in some areas such as western Henan Province
Late	3500-3000 BC	Xishan	Henan Province	Increased social hierarchies

3.2.2 Longshan culture (3000-2000 BC)

The Longshan culture was named after the site found at Longshan village in Shandong Province, by Wu Jinding in 1928 (Zhang and Wang, 1993). It is generally agreed that in some areas the Longshan culture was derived from the Yangshao culture (Shaanxi and Henan Province) whereas in other areas it originated from the Dawenkou culture (Shandong), and that it flourished along the Yellow River Valleys (Sun, 2013; Zhao, 2013). The Longshan culture is noted for its highly polished black pottery, which is also known as egg-shell pottery (Figure 3.3), which was developed with the use of the potter's wheel (Craig, 2007). The population greatly expanded during this period and many settlements were built using walls of stamped earth, with some sites becoming large political and economic centers. Violence and warfare increased and became more widespread and human sacrifice became more common during the late Longshan period (Liu, 2004; Shao, 2000; Zhang, 2000; Zhao, 2013). The complexity and wealth of the grave goods found buried with some individuals indicates the existence of social hierarchy within the population (Underhill, 2008; Cohen and Murowchick, 2014; Han, 2015).



Figure 3.3. Typical black egg-shell pottery of Longshan culture (photo from http://www.360doc.com/content/15/0323/11/22522322_457359563.shtml).

The practices of divination, by applying heat to animal bones and turtle shells (oracle bones), strongly suggests that the Longshan people shared common beliefs and possibly religion, and writing systems may have also been practiced (Gao, 2009; Shao, 2005). There is evidence of the beginning of metallurgy during the Longshan period, and copper and bronze were used for making small implements and ornaments (Linduff et al., 2000). By approximately 2000 BC, the Longshan culture of the Yellow River Valleys declined and was replaced by the Erlitou culture (which many scholars believe represents the Xia Dynasty) and the Yueshi culture in Shandong (ca. 1900-1500 BC) (IA CASS, 2003; Liu and Chen, 2003; 2006; Xu, 2009; 2014).

3.3 Shang Dynasty (1600-1046 BC)

Most Chinese historians believed that the Xia Dynasty (ca. 2100-1600) was the earliest civilization in China, with the Erlitou site regarded as its capital (Zou, 1980; IA CASS, 1999; 2014; Chen, 2004; Allan, 2007). However, this topic is the subject of intense academic debate and some scholars consider the Xia Dynasty a legend or a myth (Allan, 1984; Thorp, 1991; Liu and Xu, 2007). As a result of these controversies, the Xia Dynasty will not be discussed here. Yet, there is no doubt that China entered a significant phase of civilization and technological

advancement with the establishment of the Shang Dynasty at approximately 1600 BC (Zhang, 1980; Thorp, 2005; Zhang et al., 2007).

Originally, the Shang were a tribe who lived mainly along the lower reaches of the Yellow River in Hebei Province, but rapidly extended their territory to include northern and central Henan Province (Ding, 1988; Wang, 2011b; 2005). It is believed that the Shang banded together several tribes to defeat the Xia, and this allowed them to become the dominant power in the Yellow River Valleys for over seven centuries (Zhang, 2008; Huang, 2010). Various Chinese texts, such as: *Mencius* (孟子), *Zuo Zhuan* (左传), *Shiji* (史记), and the *Bamboo Annals* (竹书纪年) mention important events of the Shang (Sima, 2006a; Anonymous, 2009; Mencius, 2012; Zuo, 2015), but these works were written hundreds of years later than the actual events and their veracity is debated. However, much of this textual evidence has been confirmed by archaeological evidence (XSZCP Group, 2000; Wang, 2015a), with more than 20,000 divinations inscribed on oracle bones recovered at the site of Yinxu near the town of Anyang in Henan Province (Figure 3.4).

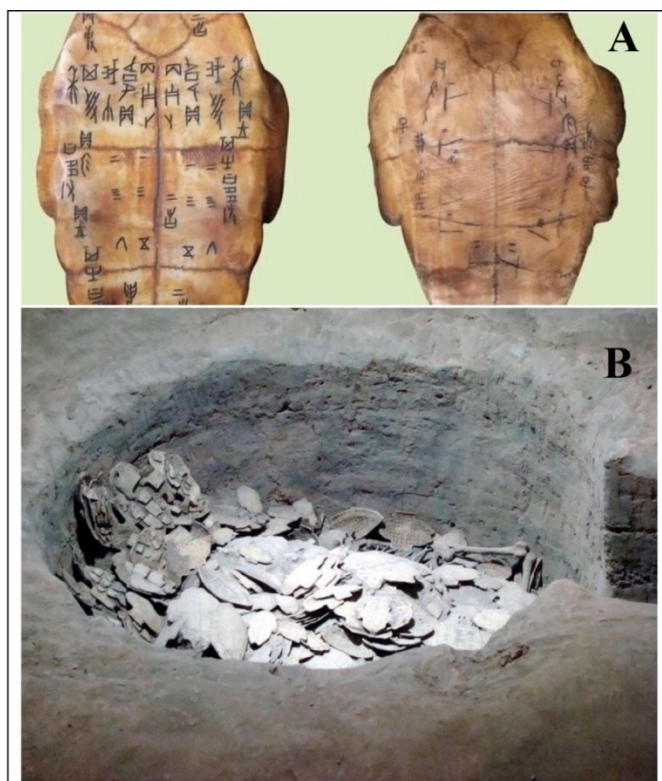


Figure 3.4. A) Oracle bone inscriptions on turtle shells from the Shang Dynasty site of Yinxu, Henan Province. B) Excavation pit of oracle bones from the Shang Dynasty site of Yinxu, Henan Province (photos from the Yinxu Museum, Anyang, China).

These inscriptions on ox scapulae or turtle shells represent the earliest confirmed Chinese writing and detail important information such as: the complete royal genealogy of the Shang Dynasty, divination practices, and rituals of the late Shang Dynasty court (Keightley, 1978; Wang, 2007a). Thus, rites, divination, and ceremonies were of vital importance to Shang society, and ancestor worship played a particularly prominent role (Allan, 2010; Song, 2010). There was a large amount of human and animal sacrifice at Shang Dynasty sites, and this practice was used to aid communication and as tribute to the dead (Huang, 2004; Tang, 2004; Wu, 2012). Sophisticated bronze manufacturing techniques were fully developed during the Shang period. Various types of cast-bronze artifacts were found at excavated sites, which were used by the upper classes both as ritual vessels and grave goods (China National Museum, 2009a; Li, 2007a).

The Shang Dynasty can be divided into two phases: an early phase (known as Erligang, ca. 1500-1300 BC) and a late phase (known as Anyang, ca. 1300-1050 BC) (AIHP, 2001; IA CASS, 2003; Sun, 2015). As a result of raids from northwestern tribes and due to the fact that the political power of the Dynasty was insecure in the early phase, the Shang moved their capital five times (Chen, 2001; Zhu, 2007; Sun and Lin, 2010). With the final move to Yin, the modern city of Anyang, Henan Province, the Shang state grew strong and inaugurated the golden age of the Dynasty. Today the site is known as the ruins of Yin, or Yinxu, and is known for large-scale palace foundations, ritual temples, enormous royal and elite tombs, chariot burials, and countless sacrificial burials (Figure 3.5). In addition, beside the large number of oracle bones, thousands of exquisite bronze, jade and ceramic artifacts have been unearthed at Yinxu. These objects clearly demonstrate that the Shang were a technically advanced civilization (IA CASS, 2007; Li, 2007b; Tang, 2009; Campbell, 2014).



Figure 3.5. Aerial view of the royal tombs at the site of Yinxu, Henan Province, China (photo from the Yinxu Museum, Anyang, China).

3.4 Zhou Dynasty (1046-221 BC)

The state to the west of the Shang, along the Wei River Valleys, was known as the Zhou. King Wu of the Zhou conquered the Shang at the Battle of Muye around 1046 BC and founded the Zhou Dynasty (Li, 2002; Bai, 2010a). The Zhou maintained their old capital, Feng, for the religious and ceremonial significance of its royal temples, but they built a new capital and administration center at the site of Hao, near the present day city of Xi'an (Jun, 2005; Tian, 2009). The Zhou Dynasty lasted until the foundation of the Qin Dynasty in 221 BC. However, the actual political and military control of China by the Zhou court only lasted until 771 BC (Yang, 1999). Historians divided this era into two periods: the Western Zhou (1046-771 BC) and the Eastern Zhou (771-221 BC) (Shaughnessy, 1999; Lee, 2002).

3.4.1 Western Zhou (1046-771 BC)

The historical events and deeds of the early Zhou kings are recorded in a number of works, which date back to the Western Zhou period. These documents include: *Shang Shu* (Book of Documents, also known as *Shu Jing*, 书经), a collection of historical texts which are believed to be the earliest writings of China's traditional literature, and the *Shi Jing* (Book of Songs, 诗经), a collection of poetry (Cai, 1987; Yang, 2010; Wang, 2015b). New archaeological

sources from this period are being constantly discovered in the form of inscriptions on bronze vessels and artifacts, some of which are hundreds of characters long, and these provide extensive details about the life and times of the Zhou Dynasty (Figure 3.6) (Zhang, 1983; Rawson, 1999; SACH et al., 2011). The Zhou Kings took the title of Son of Heaven (Tian zi, 天子), and they legitimized their rule by invoking the “Mandate of Heaven”. This change of perspective had important repercussions on all aspects of society from ceremonies to rituals, and the practice of human sacrifice declined during this period (Zhao and Guo, 2004; Zhang, 2007; Xu, 2012). In contrast to the Shang who had their main seats of political power in modern-day Henan and parts of Shanxi and Hubei Provinces (the so called Central Plains), the main center of the Western Zhou were located in Shaanxi Province (Figure 3.7) (NBCR, 1999; Li, 2007c; Sino Maps Press. 2014a).



Figure 3.6. The San Family Plate from the Late Western Zhou Dynasty, Shaanxi Province, China. Text inside of the plate describes a land contracts between two small states (photo from http://blog.sina.com.cn/s/blog_133387d7e0102vlde.html).



Figure 3.7. Map showing the territory of the Zhou Dynasty at approximately 1000 BC (from https://commons.wikimedia.org/wiki/File:Territories_of_Dynasties_in_China.gif#/media/File:Territories_of_Dynasties_in_China.gif).

The state structure of the Zhou was more complex compared to the Shang Dynasty. When they established the Dynasty, the Zhou invested members of the royal family, favored adherents, and allies with the authority to rule over more than 100 separate territories of the conquered land. Later, those hereditary fiefs, so called Zhuhou (诸侯) became increasingly powerful and independent of the Zhou court (Sima, 2006b; Li, 2007d; Chao, 2016). These subordinate rulers were given ranks that were later systematized into a hierarchic order. During the late Western Zhou period, the Zhou were frequently attacked by the Quanrong barbarians, and were forced to move their capital east to Luoyang in 770 BC. After this move, the Zhou continued to reign nominally for another 500 years even though the court no longer had real military, political, or economic power and authority (Wang, 1994; Li, 2007c). It was during this period that China entered into an age of struggle for hegemony between the great states and feudal lords (Sima, 2006b; Huang, 2015).

3.4.2 Eastern Zhou (771-221 BC)

The Eastern Zhou Dynasty is divided into two phases (Li, 1956; Lv, 2009). The early phase is known as the Spring and Autumn period (770-475 BC), which is named for the work: *Spring and Autumns Annals* (Chunqiu, 春秋), a chronicle of the state Lu (the birthplace of Confucius) between 722 to 481 BC (Gu, 2015). The later phase is called the Warring States period (475-221 BC), and this derives its name from *Zhanguo ce* (Record of the Warring States, 战国策), a historic work compiled in the 1st century BC of the Han Dynasty (Liu, 2007).

During the Eastern Zhou period, the more powerful states began to annex the smaller states, and as the lords gained power, they unlawfully declared themselves to be kings (王) of their territory (Li, 2007c; 2007d; Feng, 2009; Zuo, 2105). By the 5th century BC, most of the small states had disappeared and only a few larger states were left. In 453 BC, one of the largest states Jin (晋) was split into three parts, which became the states of Han (韩), Zhao (赵), and Wei (魏), and this marks the beginning of the Warring States period (Sima, 2009; Lv, 2011; Zuo, 2001). The main location of the activities and battles during the Spring and Autumn period was on the Yellow River Plain and the Shandong Peninsula as well as the Huai and Han River Valleys (Sino Maps Press. 2014b). The territory eventually expanded to include the present-day Provinces of Shaanxi, Shanxi, Hebei and the Yangzi River Valley in south (Tong, 2009; Qin, 2013; Chen, 2014).

Over the course of the Warring States period, seven major states fought each other for supremacy: the three Jins (on the Shanxi plateau), the Qi (齐) (in the east of China, centered on Shandong Peninsula), the Qin (秦) (in the far west, with its core in the Wei River Valley and Guanzhong Plains), the Chu (楚) (in the South of China), and the Yan (燕) (in the northeast, near modern Beijing). Additional areas such as present-day Sichuan (Shu, 蜀) and present-day Zhejiang (Yue, 越) were also brought under the control of Chinese culture during this period (Figure 3.8) (Sino Maps Press. 2014c). This period was an era of intensive warfare, and all of these states were in competition with each other in military, social and political spheres (Yang, 2003; Su, 2014; Yu, 2015).



Figure 3.8. Map of the seven major states during Warring States period (from https://commons.wikimedia.org/wiki/File:Territories_of_Dynasties_in_China.gif#/media/File:Territories_of_Dynasties_in_China.gif).

The Eastern Zhou Dynasty is also known as the Golden Age of Chinese philosophy, and a broad range of thoughts and ideas flourished during this period. Confucius (considered the greatest Chinese philosopher and founder of Confucianism), Laozi (founder of Taoism), Mozi (founder of Mohism), Shang Yang and Han Feizi (who developed of ancient Chinese legal system), and many other theorists emerged during this period (Waley, 1994; Confucius, 2006; Yao and Wang, 2015). These thoughts and ideas, known as the Hundred Schools, have profoundly influenced the lifestyle and social consciousness of China as well as the rest of Asia for thousands of years (Lv, 2009; LHPEO, 2011).

There was also an unprecedented development of technology during this period (IA CASS, 2004; Needham, 2015). New manufacturing techniques and processes were introduced, and bronze art reached a high level of excellence during the late Western Zhou period (Rawson, 1995; CBV EB, 1996; Li, 2005). Between the 6th to 5th centuries BC, the casting of iron and steel replaced bronze as the dominant metal used in warfare and farming, and this led to

considerable advances in productivity (China National Museum, 2009b; Liu, 2010). Large economic projects such as the building of: canals, dams and defensive walls were also completed during this period. For example, the Dujiangyan Dam, which controlled the Min River in Sichuan Province, and the Zhengguo Canal, which irrigated a large area of the Guanzhong Plain, both were implemented by the state of Qin, to increase agricultural output (Li, 1956; Chen, 2002; Ye, 2014).

3.5 The First Empire: The Qin Dynasty (221-206 BC)

With advances in political and military organization, the Qin were able to conquer the six other rival states (Li, 2007e; Yang, 2015). The first Emperor, Qin Shi Huang (260-210 BC), successfully unified China in 221 BC, and created an Imperial state, which lasted for over 2000 years (Twitchett and Loewe, 2007; Jin, 2012). During his reign, the territory greatly expanded to include: the Gansu and Qinghai Plateaus to the west, modern-day Guangdong and Guangxi Provinces to the south, beyond the Yellow River and the Liaodong Peninsula to the north, and all the way to the ocean in the east (Figure 3.9) (Sino Maps Press, 2014d; Feng, 2015).

The first Emperor introduced a series of reforms to consolidate his central power. He completely abolished feudalism, and deprived the power of many old and prominent families and moved them to the capital, Xianyang (near present-day Xi'an), in order to prevent the revival of feudalism (Lv, 2005; Chang, 2007). The Empire was divided into administrative units: 36 commanderies or prefectures (jun) which were subdivided into a variable number of counties (xian), then further divided into districts (xiang), and finally into hundred-family units (li). Administration duties were entrusted to officials that were nominated by the Emperor (Yang, 2003; Lewis, 2007). The Emperor eliminated all of the Hundred Schools and embraced Legalism, or a system that required people to follow laws or be punished as the ideology of the Empire (Jian, 2001; Bai, 2010b). Some of the Qin laws we know today came from the *Shuihudi Qin Bamboo texts* (睡虎地秦简, sometimes called Yunmeng Qin Jian), which are early Chinese texts written on bamboo slips that were discovered in 1975 in a tomb belonging to a Qin administrator at Shuihudi, Hubei Province. It contained important information about the law, government organization, military affairs and also many aspects of people's private lives during the late Warring States to Qin Dynasty periods (Shuihudi Qin Bamboo Slips Group, 2001). Further, the Emperor standardized the system of weights and measures and established a

uniform system for writing and currency. These changes had the effect of promoting significant political and economic unity through the Empire (Ban, 2007; China National Museum, 2009c).



Figure 3.9. Map of the territory controlled by the Qin Dynasty around 200 BC (from https://commons.wikimedia.org/wiki/File:Territories_of_Dynasties_in_China.gif#/media/File:Territories_of_Dynasties_in_China.gif).

A number of public work projects were undertaken by the Qin (Cotterell, 1981; Teng, 2002; Zhao, 2002). An impressive road system tying together different regions, with a total length of 6800 km, was built for both military and economic activities. In addition, the Ling Canal was constructed for irrigation as well as commerce, and this connection between the north and south aided the political expansion into the southwest of China (Chen, 2002; Ye, 2014). One of the most spectacular structures, the Great Wall, was completed as the demarcation line between China and the various nomadic groups by connecting the numerous walls that had been built by the former states (Li, 1975; Yang, 2014). Millions of laborers were employed on these large scale construction projects mentioned above, as well as in the building of the Imperial Palace and the Emperor's enormous mausoleum (Sima, 1961; Gao and Xu, 2013). Although the tomb

itself has not yet been excavated, various sites surrounding the tomb have been uncovered. The most famous of these discoveries is the Terracotta Army or Warriors. Over 6000 life-sized and intricately detailed statues equipped with weapons, horses and chariots, which were supposed to protect the Emperor in the afterlife, have been discovered (Figure 3.10) (Yuan, 1986; 2002; Duan, 2011).

As a result of palace intrigue and a large scale peasant rebellion, the Qin Dynasty quickly collapsed with the death of the first Emperor, Qin Shi Huang in 210 BC (Sima, 1961; Yang, 2015). Although the Qin Dynasty only survived for a short time, it had a profound effect on the administrative, economic and social structure of the Chinese Empire for thousands of years. The successors to the Qin were the Han Dynasty (202 BC to 220 AD) (Han and Zhao, 2010; Liu and Bai, 2010), but as this and the subsequent Dynasties are not the focus of the three published papers presented in chapters 4-6, they will not be discussed in this thesis.

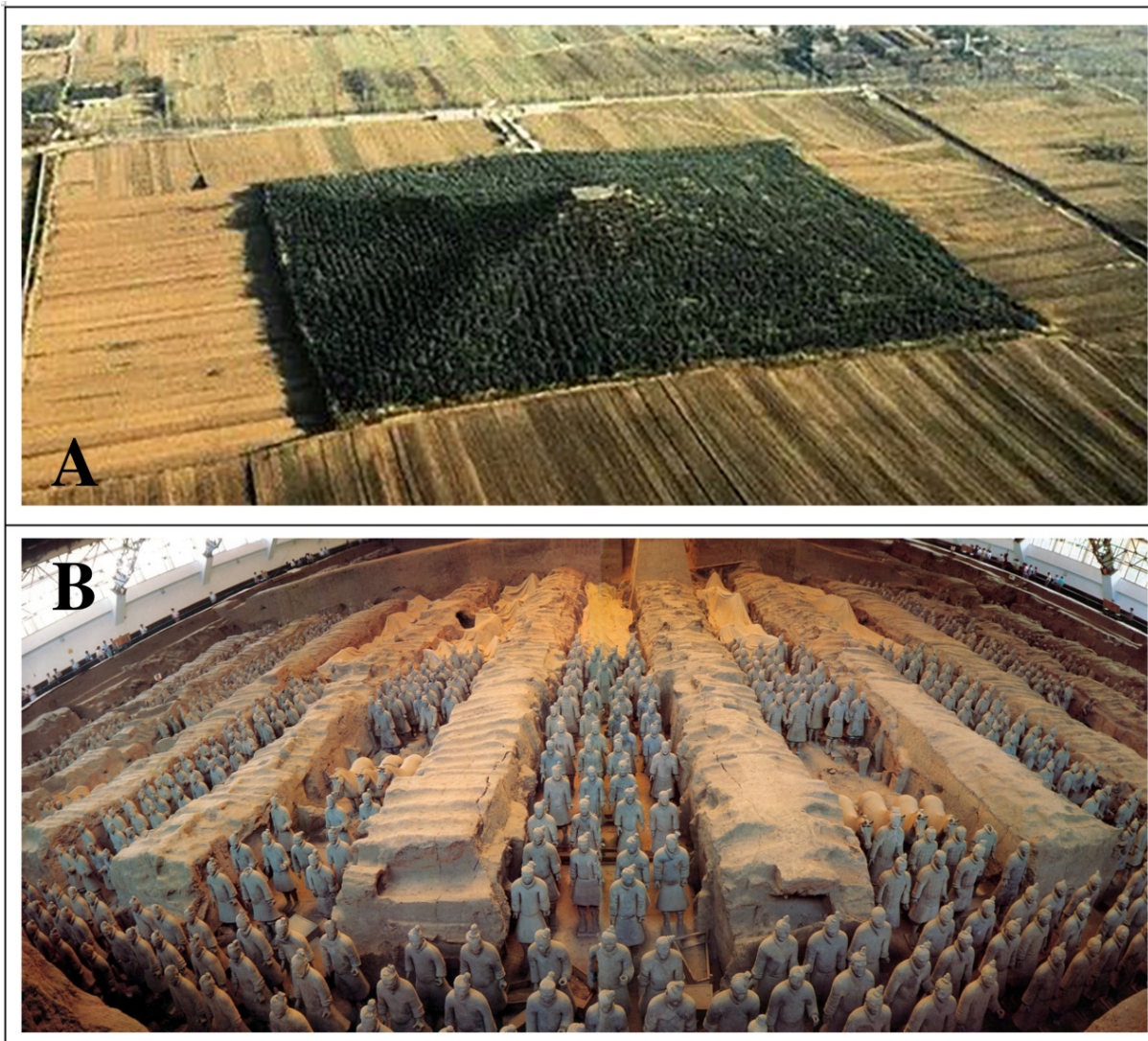


Figure 3.10. A) Aerial view of the mausoleum of the first Emperor of China, Qin Shi Huang. B) The Terra Cotta Army that guard the tomb of the first Emperor of China, Qin Shi Huang (photos from the Qin Shi Huang Mausoleum, Xi'an, China).

3.6 Dietary Trends in Ancient China

3.6.1 Agriculture division between north and south China

Chinese civilization was based on intensive farming (Scarre, 2007; 2013), but geographic boundaries between north and south China have given rise to different agriculture practices as far as back to 5th millennium BC (Wang and Xu, 2003; Liu and Xiang, 2005). The outstanding geographic feature of north China is the Yellow River, which generally flows eastward from the Qinghai-Tibetan Plateau and together with its tributary, the Wei River crosses through the

Central Plains to empty into Bohai Bay (Figure 3.11) (Zhao, 1995; Wang and Li, 2009; Lv, 2012).



Figure 3.11. Map showing the division between North and South China, as well as, different geographical features.

As mentioned above, the middle and lower Yellow River Valleys were the origins of the ancient Chinese civilization, and these areas were the most prosperous regions during the Neolithic to the early Imperial period (SACH, 2009; Wang, 2013b). Geographically, this region consisted of uplands in the west, large fertile plains in the center and a combination of highland and riverine basins in the east. It is a region suitable for growing millet, sorghum, wheat and beans (Chen, 2002; Zhou, 2007). In modern China, northern people have a diet that is centered on wheat-based foods including various types of noodles, dumplings and breads (Huang, 2014). However, millet was the predominant staple food in northern China for thousands of years since the emergence of agriculture (Zhang, 1998; Yan, 2000), and this has been confirmed by numerous archaeological findings (Zhao, 2005; China National Museum, 2009d). For example, at the Cishan site (Hebei Province), dating to 5300 BC, millet remains were found in over a hundred different storage pits with a capacity of 50 tons, evidence that a mature form of millet

agriculture was practiced in north China at this time (Figure 3.12) (Sun et al., 1981; Tong, 1984; Qiao and Liu, 2006).

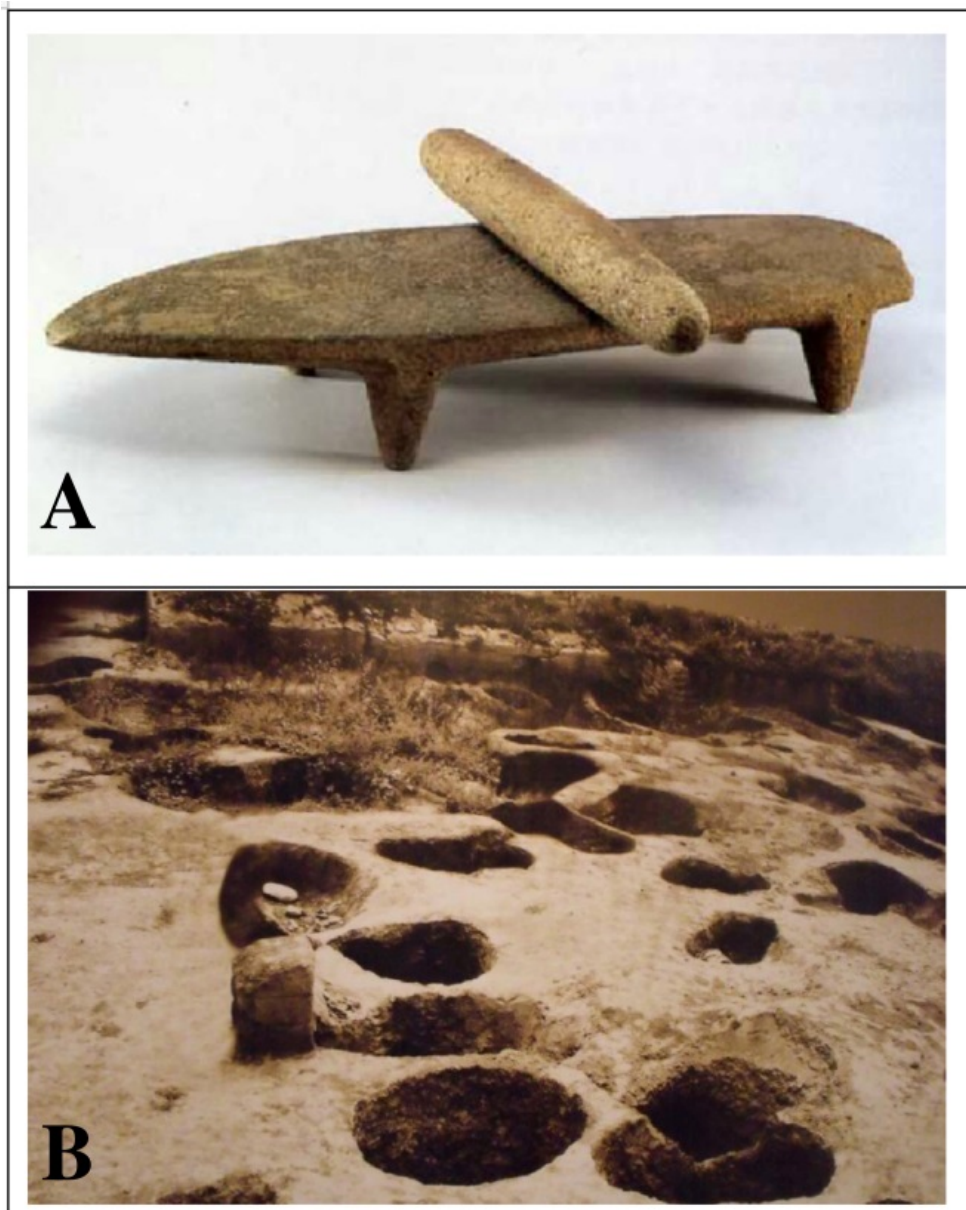


Figure 3.12. A) Neolithic grinding stone and B) millet storage pits from the Cishan, Hebei Province (photos from the Cishan Cultural Sites Museum, Wu'an, China).

In contrast, different agricultural practices prevailed in the south of China which is separated from the north by the Qinling Mountains and the Huai River, and the main watershed in this region is Yangzi River (Wang and Li, 2009; Lv, 2012). Compared to northern China, the climate is warm and humid, and this proved ideal for intensive rice cultivation (An, 1989; Chen, 2005; Lu, 2006). The earliest domesticated rice remains in this region were found at the Shangshan

site (9000 to 11000 BP) in Zhejiang Province (AIZP and Pujiang Museum, 2007). In modern times, rice is still the preferred crop of the people of southern China. Thus, there has existed a north-south divide in terms of diet in China that goes as far back to the Neolithic period.

3.6.2 Reviewing subsistence patterns from the Neolithic to Qin Dynasty

Although the timing and reasons for the transition from hunting and gathering have not been fully elucidated, archaeological evidence from north China (charred millet grains and farming tools) indicates that millet cultivation was practiced at early Neolithic sites such as: Xinglongwa (ca. 8100-7200 BP) in the northeast, Peiligang (ca. 7500-6900 BP) in the central Yellow River Valleys and Laoguantai (ca. 6000-5000 BP) and Dadiwan (7500-6800 BP) in the northwest (Underhill, 1997; Li, 2003; You, 2008). For example, at the Baijia site of the Laoguantai culture (7500-6500 BP) in the Wei River Valley of Shaanxi Province, human diet included millet and probably aquatic foods such as fish and shellfish (IA CASS, 1994). In contrast, at the Jiahu site (ca. 9000-7800 BP) in the southern part of the Yellow River Valleys, rice was found to be an important staple crop (Chen et al., 1995; Zhao and Zhang, 2009). Additional studies have found that dogs and pigs were the focus of animal husbandry practices with pigs likely to have been domesticated by 8000 BP (Lu, 1999; Yuan, 2015). However, due to the fact that numerous remains of butchered wild animals were found at the above mentioned sites, most archaeologists believe that early agriculture was an occasional or temporary activity with hunting and fishing being the dominant subsistence practices during the Middle Neolithic (Yan, 1992; Wang, 2004a).

During the Late Neolithic, millet based agricultural practices became more efficient and important to the people of northern China (Zhang, 2004; You, 2008). At many Yangshao cultural sites, large storage pits filled with millet were discovered, indicating that millet was a significant component of the diet. The Yangshao people mainly grew foxtail millet, but also broomcorn millet, sorghum, rice and possibly hemp and canola (An, 1989; Gong, 2002). Dogs and pigs were commonly kept and fed a substantial quantity of millet (Yuan and Flad, 2002). In addition, domesticated chickens were present at a number of sites during this period (Peters et al., 2015; Xiang et al., 2014; Yuan, 2015). However, while many individuals of the Yangshao culture ate large quantities of millet with only small amounts of animal protein, other Yangshao period sites such as Jiangzhai, in Shaanxi Province, still relied on hunting and gathering for sustenance (Luo, 2009).

Archaeological excavations found that millet continued as the primary grain during the terminal Neolithic or Chalcolithic. Foxtail millet was grown more widely in north China, whereas, broomcorn millet seems to have been more abundant in the drier regions, such as the central area of modern-day Henan Province (Lee et al., 2007, You, 2008). Rice and wheat (introduced from the West) have also been found at some Longshan sites in the Provinces of Shandong and southern Henan (Betts et al., 2014; Crawford et al., 2006; Zhao, 2007; Liu and Fang, 2010). For example, at Liangchengzhen, the largest Longshan site so far discovered in Shandong, the researchers found that millet was the primarily crop for animal fodder, whereas, rice increased in importance for human diets (Crawford et al., 2005; Lanehart et al., 2011). Pigs were the most common source of meat for humans, but domestic cattle, sheep and goats were (introduced from the West) also present during this period at sites along the Yellow River Valleys (Cai et al., 2014; Zhang et al., 2013).

During the Shang Dynasty, oracle bone inscriptions and historical texts such as *Shi Jing* (诗经) recorded that foxtail millet was the staple crop for the Shang people (Wang, 1985; Chen, 2007; Wang, 2015b). Recent archaeobotanical evidence shows that wheat was the second most represented crop next to foxtail millet during the Shang period (Zhao, 2009). Although, rice remains have been found at Anyang, they constituted a negligible proportion of the dietary grains. Thus, most scholars believe that rice was a trade good rather than grown locally at the Yinxu site (Tao, 2006; Song, 2011; Wang, 2011a). The variety of animals offered for sacrifice indicated that extensive forms of animal husbandry were practiced. In addition, the raw materials found at the bone workshops of Yinxu came from a variety of different animals including: cattle, sheep, deer, pig, dog and horse. Some of these animals may have been captured by hunting, but it is believed that the majority were bred and domesticated by the Shang people (Song, 1999). In addition, inscriptions on oracle bones mentioned that some officers had names of “Many Dogs” (duo quan, 多犬) or “Many Horses” (duo ma, 多马) indicating that animal management was part of the duties of some government officials (Liu, 1994; Guo, 2015).

During the Zhou Dynasty, historical sources frequently mention that there were five farmed crops that were important during this period. The Five Grains (Wugu, 五谷) traditionally date back to the work, *The Classic of Herbal Medicine* (Shennong Bencaojing, 神农本草经), which

is reputed to be a record of an oral tradition compiled between about 200 and 250 AD (Gu, 2007). Although the identity of the five crops has varied over time, in most pre-Qin works, such as *Liji* (礼记) and *Zhouli* (周礼), the crops mentioned are: foxtail millet (稷), wheat (麦), soybean (豆), broomcorn millet (黍) and hemp (麻). However, in some versions hemp is replaced with rice (稻) (Dai, 2014; Duke of Zhou, 2014). In *Qinmin Yaoshu* (齐民要术), the famous Chinese book that described agricultural knowledge before the 6th century AD in northern China, it lists: millet, sorghum and beans as the most important in terms of human diet during the pre-Qin period (Jia, 2009). Animal husbandry was significantly developed during the Zhou period. Written records mentioned six kinds of animals such as pig, dog, cattle, sheep/goat, horse and chicken as being very important domestic breeds during the pre-Qin period. They were widely used for food sources, sacrificial or ritual killing and as sources of labor and for military purposes. Further, goose and duck were raised for supplementary food sources (Zuo, 2011; Duke of Zhou, 2014).

Historical and archaeological evidence indicates that millet continues to be a staple food in the main territory of the Qin state, the Loess Plateau including Gansu and Shaanxi Provinces, before the unification of the Empire in 221 BC (Fan, 1986; Zhang and Fan, 2007). In particular, the *Shuihudi Qin Bamboo texts*, described that the Qin state stored a large amount of millet in the capital's granary (Shuihudi Qin Bamboo Slips Group, 2001). In *Shiji* (The Records of the Grand Historian, 史记, which is regarded as a monumental history of ancient China finished around 94 BC by the Han Dynasty official Sima Qian), Sima mentioned that the Qin people viewed soybeans as a crop for the poor, and thus they avoided eating these. Not until the Han Dynasty, under the encouragement of the government, did the cultivation of wheat become popular in this region (Sima, 1961; Wang, 2004b). In addition, *Shiji* and *Hanshu* (Book of Former Han, which was completed in 111 AD by Ban Gu) also recorded that it was common to eat dog meat during the Qin and Han Dynasties, since many people made their living by the butchering dogs (Sima, 1961; Ban, 2007). Fish and soft-shelled turtle were also the popular additional foodstuffs for daily life as well as wild animals such as: pheasant, quail, hare and deer (Yao, 2011).

3.7 Social Stratification in Prehistoric China

It is generally agreed that during the Early Neolithic period that societies were egalitarian and no social hierarchies have been observed (Ren and Wu, 2010). During the Late Neolithic period, the Yangshao culture rapidly increased in population and site size, but many of these sites show little evidence of social differences (Zhang and Wei, 2004). For example, at the Banpo site, the main houses and tombs were both of similar size and shape, suggesting that there were no major social distinctions in the individuals of this community (Lee, 1993). However, some sites do show evidence of emerging social hierarchy. For example, at Xipo in western Henan Province, some families or groups of individuals were buried with valuable objects (cinnabar, jade, etc.), and the large number of pig bones recovered suggests that they were able to hold large feasts (Ma, 2003; Liu, 2004). During the Longshan period, societies became more socially stratified (Liu and Chen, 2012; Pei, 2014). For example, at the Taosi site in southern Shanxi Province the large number of burials, more than a thousand, can be grouped into three classes on the basis of grave goods. The larger sized tombs, approximately 3 meters long and 2-2.7 meters wide contained 100 to 200 grave goods including: painted pottery with dragon designs, alligator drums, jade artifacts, giant chime stones and whole pigs. In contrast, some tombs were narrow pits with very few or no grave goods. It is notable that the majority of the high status burials were males, and it is speculated that this status could have been conferred through heroic acts related to warfare (Yan and He, 2005; Han, 2011). However, such burial differences are mainly present in the areas of Shandong and southern Shanxi Provinces, and this suggests that social stratification varied among regions during the Late Neolithic period (Zhu, 2014).

From the Shang Dynasty onwards, China became a highly bureaucratic and meticulously ordered society. The large distinctions of status and wealth among the living were increasingly applied to the dead (Song, 1994). Elites were usually buried in an underground chamber and were provided with numerous grave goods and human sacrifices. For example, the tomb of Lady Fu Hao, who was the wife of King Wu Ding of the Shang as well as an army general, is one of the most famous in China at the site of Yinxu near modern-day Anyang. Her tomb, a 5 meter long and 3.5 meter wide chamber contained a lacquered wooden coffin and 468 bronzes, 755 jades, and over 6880 cowry shells (Figure 3.13) (IA CASS, 1989). In addition to the royal tombs at Yinxu, burials can be identified into different categories which reflect the remarkable stratification of political and social life during the Shang Dynasty. Examples include: 1. Large

tombs with ramps; 2. Burials of individuals who followed their tomb owner to their death; some were buried in the chamber of the tomb owners while other were buried in the vicinity of the tomb; 3. Medium size pits; 4. Shallow pits; and 5. Burials in refuse pits and disused wells (Gong and Xu, 2011). Scholars have determined that a hierarchy existed among the sacrificed victims with three groups identified. The first group are individuals that are buried in waist pits (yaokeng, 腰坑; below the burial chamber) or in the four corners of the burial chamber.



Figure 3.13. The tomb of Lady Fuhao at the Yinxu site in Henan Province (photo from the Yinxu Museum, Anyang, China).

These individuals are buried with a bronze or jade dagger-axe and were supposed to guard the body of the deceased. The second class of individuals are those that are buried in their own coffins with grave goods, even with their own sacrificed victims or attendant dog, and are believed to be high status relatives, retainers or personal attendants of the deceased. The third type of individuals, were usually young males, between 15 to 35 years old, but some children have also been found. They appear to represent slaves or captured warriors in battle, and they were decapitated or dismembered, and their heads were frequently buried in the pits with their bodies in the ramps (Figure 3.14) (IA CASS, 2007; Tang, 2009).

In general, the large-scale human sacrifices of the Shang Dynasty declined during the Zhou

Period and were banned after the Qin Dynasty (Zhang, 2001). In place of human sacrifices, individuals from later periods were buried with “spirit objects” (明器). These included daily utensils, musical instruments, weapons, armor and intimate objects as well as figurines that acted as symbolic representations of soldiers, servants, musicians, houses and animals, rather than the real individuals or objects (Wu, 2016). The individual use of “spirit objects”, in particular the combination and total number of bronze ritual vessels Ding (鼎) and Gui (簋), was strictly according to the social rank during the Zhou period (Yu and Gao, 1978; Duke of Zhou, 2014).



Figure 3.14. A) Decapitated bodies buried on the ramp of a royal tomb at Yinxu. B) Human skulls buried in the pit of a royal tomb at Yinxu. C) Burial of a sacrificed warrior at a royal tomb at Yinxu (photos from the Yinxu Museum, Anyang, China).

For example, only a Zhou King could be buried with nine Ding and eight Gui (九鼎八簋) since this combination was a symbol of authority (Qin, 2013). However, this practice gradually disappeared during the Warring States period and was no longer used during the Qin Dynasty, as Imperial authority was represented by the Imperial Seal of China used by the Emperor (Yang,

2003; Lv, 2005). In addition, historical texts also discuss other material differences between the nobility and the common people (Wang, 2007b; Yang, 2010). For example, bronze vessels and jade were reserved for nobles, and ordinary people were not allowed to use these in their daily life or as grave goods (Li, 2007e). The book, *Guoyu* (Discourses of the States, written by Zuo Qiuming who lived from 502 to 422 BC), describes how dietary habits were influenced by social status. A king could eat everything, the rulers of small states could eat cattle, senior officials could eat sheep, middle officials could eat pig, lower officials could eat fish and the common people could mainly eat only vegetables (Zuo, 2015). Further, during the Han Dynasty the book *Liji*, discusses how the number of dishes served at a meal was determined by an individual's status and age during the pre-Qin period, with higher status and older individuals having more dishes and greater dietary options (Dai, 2013). Mencius (372–289 BC) also mentioned that the elders of the common people were given elevated status and were allowed to wear silk and eat meat (Mencius, 2012).

3.8 Stable Isotope Ratio Analysis in Chinese Archaeological Research

In 1984, Cai and Qiu were the first to introduce the stable isotope ratio analysis method into Chinese archaeological studies. They reported $\delta^{13}\text{C}$ results of human and animal collagen from several famous Chinese Neolithic sites, such as Yangshao and Taosi (Cai and Qiu, 1984). Their study traced millet domestication in northern China to as early as 7000 BP and also found that there was a difference in subsistence patterns between north and south China since at least the Neolithic. North China had diets that were mainly based on millet (C_4 plant), whereas, southern China had diets based on rice (C_3 plant). However, after this pioneering study, there was little isotopic research on Chinese material for 20 years. Zhang et al. (2003) published $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from a number of important Chinese archaeological sites such as: Yinxu, Liulihe, Xinglongwa and Hemudu and explored differences in dietary patterns between north and south China as well as between farming and hunter-gather groups. In the last decade, there has been an explosion in the number of the stable isotope studies applied to Chinese human and animal archaeological materials and these will be briefly reviewed below.

3.8.1 Agricultural practices in China

During the Neolithic, millet and rice were the two most dominant edible crops in northern and

southern China, respectively. It was not until the late Neolithic/early Bronze Age that wheat (a western crop) started to be consumed (Lu, 1999). Hu et al. (2006) investigated human and animal diets from the early Neolithic (9000 to 7800 BP) site of Jiahu in Henan Province. They found that the inhabitants of Jiahu mainly relied on hunting and gathering during the early periods of settlement, shifted to gathering and fishing during the middle period, and it was not until the late phase of occupation that rice and domestic animals made an increased contribution to the human diet. In another study, Hu et al. (2008) examined individuals from the early Neolithic site of Xiaojinshan in the lower Yellow River Valley, which is attributed to the Houli Culture and dates to about 8000 BP. Here the isotopic results indicate that humans were eating moderate amounts of millet, with other sources of protein coming from C₃ plant and animals. In addition, Hu et al. (2008) compared their results with previous published studies (Zhang et al., 2003; Pechenkina et al., 2005) of isotopic results from later sites of the Yangshao Culture (7000-5000 BP), and concluded that millet became a staple food for humans by approximately 7000 BP in northern China. Barton et al. (2009) published an important isotopic paper about the Dadiwan site located in Gansu Province. During phase 1 (ca. 7900 to 7200 BP), millet only made a fairly small contribution to human diets, but during phase 2 of the occupation of Dadiwan (ca. 6500 to 4900 BP), both broomcorn and foxtail millets made a significant contribution to the diets of humans and animals, notably dogs and pigs. In addition, there has been a growing body of stable isotope studies that have been published on human and animals remains from China (Pechenkina et al., 2005; Cui et al., 2006; Hu et al., 2007; Ling et al., 2010; Atahan et al., 2011a; Atahan et al., 2011b; Lanehart et al., 2011; Liu et al., 2012; Wang et al., 2012; Dodson et al., 2013; Alison et al. 2014; Barton and An, 2014; Liu et al., 2014; Chen et al., 2015; Zhang et al., 2015a; Zhou and Garvie-Lok, 2015). These works have helped contributed to our understanding of the timing and location of millet, rice and wheat agriculture in China.

3.8.2 Animal husbandry strategies

Isotopic analysis has also been used to learn more about the timing and means of animal domestication in China. Guan et al. (2007) conducted an isotopic investigation of pig bones from the Eastern Zhou (771-256 BC) to Wei and Jin Dynasties (220-420 AD) at the Wanfabozi site in Jilin Province and found that both wild and domesticated pigs ate mainly C₃ plants. However, the domestic pigs had much higher $\delta^{15}\text{N}$ values than the wild pigs, indicating a high consumption of animal protein, likely from human leftovers or waste. They concluded that

these unique dietary differences could be used as a means to identify domestic vs. wild pigs. Hu et al. (2009) successfully distinguished domestic pigs from wild boars at two Houli Culture sites (ca. 8500-7500 BP) in Shangdong Province by using $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results. Animal husbandry studies from Neolithic and early Bronze Age sites in the Wei River Valley found different dietary patterns for the domestic animals (Chen et al., 2012; Chen et al., 2016). The majority of the pigs showed a heavy reliance on millet, suggesting they were possibly raised by an intensive foddering strategy, but some pigs consumed less millet, indicating that they were likely cared for by herding and foraging. The domestic sheep appear to have been allowed to graze on the nearby grassland since their isotopic signatures are similar to the wild ovicaprids. In contrast, cattle have more ^{13}C -enriched results indicating an increased reliance on C_4 plants in their diet, and these elevated $\delta^{13}\text{C}$ values can be used as a means to identify cattle husbandry in northern China.

3.8.3 Subsistence differences

Another widely used application of isotopic analysis in China is the detection of subsistence patterns and differences between time periods and cultural groups. In particular, past work has focused on how social interactions and communications caused nomadic tribes and hunter/gathers to adopt sedentary agricultural practices. Dong et al. (2007) analyzed $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from humans of the Lamadong site (265-420 AD), Liaoning Province, which is attributed to the pastoral Murong Xianbei Culture. The isotopic results showed that the people mainly relied on millet and were vegetarians. The authors concluded that this group of the Xianbei population was strongly influenced by the Han Culture and quickly changed from a nomadic to a settled agriculture lifestyle. However, later studies focused on the subsistence strategies of the Tuoba Xianbei (another group of the Xianbei population) found that this branch took much longer to transition from a pastoral to a farming economy (Zhang et al., 2010; Zhang et al., 2015b). Pei et al. (2008) studied the paleodiet of individuals from the Neihengyuan site, Shanxi Province. This site belongs to the Han Culture, and while the archaeological evidence indicates that the population was engaged in agriculture, the isotopic results revealed that the people mainly relied on stockbreeding, which could have been the result of influences from the nomadic Rongdi minority population in the region. Further, isotopic analysis of individuals from the Qinglongquan site, Hubei Province, spanning the Neolithic to Eastern Zhou period, found that there was a dietary shift to more millet consumption from the early

phase (3000 to 2600 BC) to the later phase of occupation (2600 to 2200 BC) (Guo et al., 2011; Zhang et al., 2012). These differences have the ability to investigate human interactions and migrations between regions of millet agriculture and rice agriculture in this special Rice-Millet Blended Zone region of central China (Guo et al., 2011).

CHAPTER 4 Isotopic Perspectives ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$, $\delta^{34}\text{S}$) of Diet, Social Complexity, and Animal Husbandry during the Proto-Shang Period (ca. 2000 – 1600 BC) of China

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Abstract

Objectives: To examine dietary patterns and animal husbandry practices and assess the links between human diet and sex, age, burial direction/position, and social status (as inferred by type of grave goods) during the transformative Proto-Shang (ca. 2000-1600 BC) period of China.

Material and Methods: Stable isotope ratios of carbon ($\delta^{13}\text{C}$), nitrogen ($\delta^{15}\text{N}$), and sulfur ($\delta^{34}\text{S}$) were analyzed from human (n = 83) and animal (n = 36) bone collagen at the site of Nancheng in Hebei Province, China.

Results: The Proto-Shang population consumed a predominately C₄ diet ($\delta^{13}\text{C} = -6.8 \pm 0.4\text{‰}$; $\delta^{15}\text{N} = 9.4 \pm 0.6\text{‰}$), but a single individual (M70) had a mixed C₃/C₄ diet ($\delta^{13}\text{C} = -14.9\text{‰}$; $\delta^{15}\text{N} = 10.1\text{‰}$). The $\delta^{34}\text{S}$ measurement of M70 (8.8‰) is similar to the local animals (8.2 ± 2.6‰) and the other members of the population (7.0 ± 0.8‰) suggesting this individual may not have been a migrant even though the burial direction (north-south) and position (flexed) was different than the majority of the graves in the cemetery.

Discussion: From comparison with the faunal bone collagen stable isotope results, the Nancheng population ate millets with varying levels of animal protein consumption focused primarily on pigs and possibly cattle and dogs, but sheep/goats, and deer were not eaten in significant amounts. Analysis of the isotopic results in relation to other contemporary sites such as Liuzhuang and Xinzhai show strikingly similar patterns, suggesting that the sheep/goats were likely raised mainly for their secondary products (e.g. wool). No link between diet and sex was found at the population level, but when the data were sorted by age and sex, the older males (> 40 years old) were found to have significantly lower $\delta^{13}\text{C}$ values ($-6.6 \pm 0.3\text{‰}$; n = 18) compared to the younger males (< 40 years old) ($-7.3 \pm 0.5\text{‰}$; n = 8).

Further, no significant correlations between diet and burial direction/position or social status (based on the type of grave goods) were found at Nancheng, possibly indicating that the dietary social stratification of the later Shang and Zhou Dynasties had yet to be established in Chinese society at this time.

4.1 Introduction

A formative yet enigmatic era in Chinese history is the Proto-Shang period (ca. 2000–1600 BC) which occurs between the end of the late Longshang Neolithic (ca. 2200–2000 BC) and the establishment of the Shang Dynasty (1600–1046 BC) or the earliest form of the “Chinese” state (XSZCP Group, 2000). This transitional period marks a critical phase in the development of early Chinese civilization, with the formation of social systems and structures related to ritual, status, and wealth (Zhang, 1983; King and Goldman, 1992; SACH, 2009; SACH et al., 2011). The Proto-Shang people are believed to originate from north China, and were composed of a number of chiefdoms from different ethnic groups (Liu, 2004; Wang, 2005). The culture quickly grew and they expanded their influence southward to the Central Plains, where they were frequently engaged in warfare with the Xia ethnic group, finally conquering them and establishing the Shang Dynasty in 1600 BC (Zou, 1980; Ding, 1988; Li, 1989; Huang, 2010).

Over the last decades, many sites dating to the Proto-Shang culture were discovered in northern Henan Province and southern Hebei Province, and these greatly expanded our knowledge of the lifeways of these people (Zhu, 2007; Zhang, 2008; Wang, 2011). Historical sources and archaeological evidence suggest a varied subsistence strategy for the Proto-Shang based on hunting, animal husbandry, and agriculture (Zhang, 2002; Chen, 2007; Zhu, 2007; Hou et al. 2009; 2013). However, despite an increased number of archaeological excavations, little direct research has explored the diet and social complexity of the Proto-Shang people. Hou et al. (2013) were the first to report human isotopic results from the Proto-Shang period site of Liuzhuang (Figure 4.1a). Their results found the diet was based on millets, with the animal protein mainly derived from pigs, cattle, and dogs. In addition, Hou et al. (2013) examined dietary differences as related to age, sex, and burial type (pit, stone coffin, and wooden coffin) within the population, but no differences were found. While this is regarded

as pioneering research, it was limited in scope by the small number of individuals studied ($n = 21$).

Here we present the largest isotopic study of humans ($n = 83$) from a Proto-Shang site, the cemetery at Nancheng in Hebei Province (Figures 4.1a-c). The focus of this research has multiple goals. The first is to reconstruct the subsistence patterns and animal husbandry practices of this population to determine if the type of animal protein consumed was mainly centered on certain species of domestic animals such as pigs and cattle (as found by Hou et al. 2013), as opposed to other domestic animals (sheep/goats) and wild animals. The second is to assess if unique dietary patterns are linked to sex, age, and burial direction/position in the population. The third is to examine if dietary differences are linked to perceived social status, as inferred from the type of grave goods interred with the deceased (see below). This type of analysis can provide information about the mechanisms of possible social hierarchy in a pre-state level society in China.

4.1.1 Archaeological background

The Nancheng cemetery site is located on the northern side of the ancient Jian River near Handan City in Hebei Province (Figure 4.1a). Excavations at Nancheng uncovered 116 burials dating from the late Longshan period to the Tang Dynasty (960 AD – 1127 AD). However, the majority of the graves ($n = 83$) dated to the Proto-Shang period based on analysis of the recovered grave goods (see Figures 4.1b,c). Nearly all the human remains were buried in an extended supine posture, except for M51 and M70 which were both buried in a flexed posture. In addition, all graves were placed in a west to east orientation, except for five burials (M46, M51, M70, M76 and M78) which were aligned north to south (Table 4.S1). Sixty-percent of the burials had associated grave goods such as pottery, shells, and jade. In particular, three individuals (M3, M15, M87) were found with large scallop shells (*Pectinidae*) covering their faces, and some of these skeletons were associated with necklaces made of small sea snail shells (*Cypraeidae*) or cowries (Figure 4.1b). These large scallop shells have a small hole drilled through their centers and are believed to have been centerpieces of necklaces that were used here as burial masks, possibly for high status or wealthy individuals in the community. A similar necklace (also containing a large scallop shell) was found with a female in tomb M7 at the late Neolithic Yueshi culture (ca. 1900 – 1600 BC) site of Xianrentai, located closer to the coast in Shandong Province (Ren and Cui, 1998; Fang,

2010). These unique discoveries are rare for inland archaeological sites in China, and their association suggests these individuals were possible elites or migrants to the community.

4.1.2 Stable isotope ratio analysis and palaeodiet

Stable isotope ratio analysis is widely applied to reconstruct diet, animal husbandry strategies, health and nutrition, and social status in both modern and past populations (e.g. van der Merwe and Vogel, 1978; Schoeninger and DeNiro, 1984; Sealy et al., 1987; Richards et al., 1998; Fuller et al., 2004; Müldner and Richards, 2007; Choy et al., 2010; Bourbou et al., 2011; Commendador et al., 2013; Cui et al., 2015). Since body tissues are derived from the intake of food and water, isotopic ratios obtained from bone collagen reflect the average lifetime diet (including a significant portion from adolescence) of an individual or animal (Stenhouse and Baxter, 1979; Hedges et al., 2007). In general, carbon ($\delta^{13}\text{C}$) results permit detection of C_3 plants ($\delta^{13}\text{C}$ values between -20‰ to -34‰) and C_4 plants ($\delta^{13}\text{C}$ values between -9‰ to -16‰) in the diet (Smith and Epstein, 1971; DeNiro and Epstein, 1978; O’Leary, 1981; Nelson and Schwarcz, 1982). Nitrogen ($\delta^{15}\text{N}$) values are used to determine trophic level, since tissues, like bone, have a ~3–5‰ enrichment in $\delta^{15}\text{N}$ relative to diet (e.g. Schoeninger and DeNiro, 1984; Bocherens and Drucker, 2003; Hedges and Reynard, 2007; Reitsema, 2013). In addition, the combination of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurements permits the identification of marine food consumption in archaeological populations (e.g. Richards and Hedges 1999). In China, applications of these measurements have become vital for understanding the timeline for the introduction and spread of different forms of C_3 (rice, wheat, barley etc.) and C_4 (millets) cultigens to various regions (e.g. Pechenkina et al., 2005; Hu et al., 2008; Barton et al., 2009; Fu et al., 2010; Atahan et al., 2011a; 2011b; Lanehart et al., 2011; Liu et al., 2012; Atahan et al., 2014) and for reconstructing animal husbandry practices (e.g. Hu et al., 2009; Chen et al., 2012; Hou et al., 2013).

Sulfur ($\delta^{34}\text{S}$) analysis is a more recent addition to paleodiet studies. The source of sulfur in bone collagen is the essential amino acid methionine, and there is wide variation in plant values (-22‰ to +22‰) as a result of location and geology, with little isotopic fractionation between diet and consumer tissues (Krouse, 1980; Richards et al., 2001; 2003; Nehlich and Richards, 2009; Nehlich, 2015). Increased applications of sulfur measurements (combined with $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results) have shown that $\delta^{34}\text{S}$ results are useful to determine origins or

‘non-local’ individuals in a population as well as freshwater and marine protein consumption (Nehlich and Richards, 2009; Nehlich, 2015). While studies were published for Pacific Island, European and Near Eastern sites (e.g. Craig et al., 2006; Privat et al., 2007; Nehlich et al., 2011; Nehlich et al., 2012; Kinaston et al., 2013; Sayle et al., 2013; Loesch et al., 2014), only a single application of $\delta^{34}\text{S}$ analysis was previously published for China (Hu et al., 2009), making the results presented here of particular importance to Chinese isotopic studies. For more in-depth discussion of these isotopic methods the reader is directed to the following comprehensive reviews (Schoeninger, 1995; Katzenberg, 2000; Lee-Thorp, 2008; Reitsema, 2013; Nehlich, 2015).

4.1.3 Investigating social status with isotopic ratios: Considerations for China

Isotopic measurements ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$, $\delta^{34}\text{S}$, etc.) are increasingly used to investigate relationships between diet and social hierarchy in archaeological populations (reviewed in Twiss, 2012). In particular, the focus of many studies (e.g. Murray and Schoeninger, 1988; Richards et al., 1998; White, et al., 2001; Privat et al., 2002; Ambrose et al., 2003; Le Huray and Schutkowski, 2005; Kjellström et al., 2009; Jørkov et al., 2010; Yoder 2012; Kinaston et al., 2013; Quintelier et al., 2014), was the use of $\delta^{15}\text{N}$ measurements to examine if there were differences in animal protein consumption ($\uparrow \delta^{15}\text{N}$ values \approx \uparrow animal protein consumption) between social classes based on grave goods, type of burial, burial location and direction, etc. Some notable examples include: increased consumption of marine foods by individuals interred in lead coffins or mausoleums vs. common graves at the Late Roman site of Poundbury, UK (Richards et al., 1998), more animal protein and less maize in the diet of high status individuals vs. low status individuals at the Cahokia Mound 72 in Illinois, USA (Ambrose et al., 2003), greater consumption of animal/dairy protein by males buried with iron swords, shields and/or spears vs. males buried without weaponry at the La Tène period site of Kutná Hor-Karlov, Czech Republic (LeHuray and Schutkowski, 2005), increased consumption of high status foods, pork, chicken, sea turtle, and pelagic fish by wealthy individuals on the Polynesian outlier island of Taumako (Kinaston et al., 2013), and more marine and animal protein in the diet of individuals found buried in the church (more expensive location) vs. those buried in the cloister garth (less expensive location) at the post-medieval Carmelite Friary at Aalst, Belgium (Quintelier et al., 2014). These isotopic studies are valuable to bioarchaeological research since they provide an independent line of evidence

for the dietary dimensions of social inequality which are often missing in the archaeological record. However, it is important to remember that dietary variations in these populations were complicated and likely determined by a variety of factors including: ideology, culture, social and biological status, etc. While diet can be used as a symbolic representation of social relations, it must be viewed together with the specific archaeological information and background of the site and time period, and one must be cautious when interpreting and reconstructing the relationships between dietary variation and social status (for reviews see Danforth, 1999; Curet and Pestle, 2010).

In ancient China, complex and rigid systems of social organization and hierarchy were present in life and in death (e.g. Yu and Gao, 1978; Song, 1994; 2010; Dai, 2013), but how and when these traditions were first established is not clear. Historical sources provide evidence that differences in diet were present between the nobility and the common people, and that meat was viewed as a luxury item for the nobility, wealthy, or elders of a family group that was generally reserved for special occasions such as festivals or banquets (Song, 1999; Wang, 2007). For example, Zuo Qiuming who lived from 502-422 BC, described in *Guoyu: History of Zhou Dynasty States*, how during the Zhou Dynasty that the king could eat everything, the rulers of small states could eat cattle, senior officials could eat sheep, middle officials could eat pig, lower officials could eat fish, and that the common people would mainly eat only vegetables (Zuo, 2015). Further, the Chinese philosopher, Mencius (372-289 BC) wrote that the elders of the common people could wear silk and eat meat given their elevated social status in the community (Mencius, 2012), and in *Liji: Book of Rites*, which describes the customs and traditions of the Zhou Dynasty, it discusses how the number of dishes served at a meal was determined by an individual's status and age, with higher status and older individuals having more dishes and greater dietary options (Dai, 2013). In addition, social status in ancient China was also maintained in death through specific mortuary practices. Tomb size, quality and quantity of grave goods, human sacrifice, number and type of coffins, etc. were all strictly controlled based on the social standing and wealth of an individual (Qing, 2007; Wu, 2012). For example, during the Shang and Zhou Dynasties the combination and total number of bronze ritual vessels, *Ding* (used to cook or hold meat) and *Gui* (used to hold grains), buried with an individual was a sign of their social rank in the community (Yu and Gao, 1978; Tang, 2004; Wang, 2007).

Despite these historical accounts of dietary differences linked to social status in ancient Chinese society, little isotopic research has been conducted on this topic (Ling et al., 2010; Zhang et al, 2012; Zhang et al, 2014; Wang, 2014) and none was directly focused on Proto-Shang sites. At Nancheng, archaeological evidence in the form of metallurgy, (potential) written inscriptions on oracle bones, and walled settlements suggests the Proto-Shang likely had some form of social complexity and hierarchy (Underhill, 1994; Liu and Chen, 2003; Ebrey et al., 2006). In addition, the small bronze tools and weapons found at the sites of Jiangou, Beiyangtai, and Xiaquyuan indicate the development of complex technology, and the centralization of a trade specialization, which can be regarded as causal factors leading to social stratification (HPACH, 1979; Pluciennik, 2005). Even more impressive evidence is found in Proto-Shang burials in the form of different types and qualities of grave goods interred with the deceased, evidence that pronounced differences in wealth and status possibly existed in Proto-Shang society (HPICRA, 2003).

Here at Nancheng, the large number of burials recovered with different types of grave goods permits an investigation of links between diet and social status. As little is known about how social status is reflected by grave goods during the Proto-Shang period, we decided to define individuals found with no grave goods as low status, individuals buried with only pottery (excluding type and number) as medium status, and individuals buried with jade, calcite, and shells (exotic items) as high status. While far from perfect, we believe these are reasonable classifications since during the following periods (Shang and Zhou Dynasties) the type and quality of graves goods are used as one of the markers to identify social status (IA CASS, 2003). Given that after the Proto-Shang period, historical sources describe social status differences linked with the type and quantity of animal meat eaten, we hypothesize that the high status individuals at Nancheng might have elevated $\delta^{15}\text{N}$ values compared to the medium and low status individuals. In addition, as the elders of a community were revered and honored in ancient Chinese society and were described as having preferential diets with possibly more access to meat, we suspect that older individuals might have different isotopic results than younger individuals; including higher $\delta^{15}\text{N}$ values. Thus, this research can shed light on the origins of social hierarchy and complexity in relation to diet in ancient China.

4.2 Materials and Methods

The remains of 83 skeletons consisting of both adults and adolescents [10-15 years old] (no infants or children) were examined and classified by a team of physical anthropologists led by Dong Wei (an author on this paper) at the Research Centre for Chinese Frontier Archaeology at Jilin University (Table 4.S1). Age estimation and sex determination for each individual (where possible) were determined by standard methods outlined by Ubelaker (1999) and White and Folken (2000). Specifically, sex was determined by pelvic sexual dimorphism and age was estimated by morphological changes of the pubic symphysis. Rib and long bone fragments from each skeleton were selected for collagen extraction and isotopic analysis. Since only two unidentified animal species were found at the Nancheng site, faunal remains (dogs (*Canis familiaris*), cattle (*Bos Taurus*), pigs (*Sus domesticus*), sheep (*Ovis aries*) and goats (*Capra hircus*), deer (*Cervidae*), and sika deer (*Cervidae nippon*); total n = 34) were obtained from the nearby (< 3 km) contemporary site of Baicun and used as an isotopic baseline with which to compare the human results (Table 4.S2). The identification of faunal species was conducted by the Institute of Archaeology, CASS in Beijing.

Bone collagen was extracted following the standard procedures detailed in Richards and Hedges (1999) with the addition of ultrafiltration (Brown et al., 1988; Jørkov et al., 2007). Approximately, 0.5-1.0 g of bone was cleaned by air abrasion and then demineralized in a 0.5 M HCl solution at 4 °C for 2 weeks, with the acid changed every 2 days. Samples were then gelatinized at 70 °C in a pH = 3 solution for 48 hours. After purification with a 5µm EZEE[®] filter, the solution was concentrated by Amicon[®] ultrafilters (<30 kDa), and then was frozen and freeze dried for 2 days. Approximately 0.5 mg of extracted collagen was weighed in duplicate for carbon and nitrogen analysis, using a Flash EA 2112 coupled to Thermo-Finnigan Delta XP isotope ratio mass spectrometer. Approximately, 10 mg collagen was required for sulfur analysis, and to each sample 1 mg of V₂O₅ was added to ensure complete combustion. The resulting gases SO and SO₂ were analyzed in an elemental analyser (HeKaTech, Wegberg, Germany), which was coupled to a Delta V plus isotope ratio mass spectrometer (Thermo-Finnigan, Bremen, Germany). The inorganic international standards NBS127 (20.3‰), IAEA-S1 (-0.3‰), IAEA-S2 (21.5‰) and IAEA-SO-5 (0.5‰) and two organic standards NIST bovine liver 1577 b (7.5‰) and IVA protein casein (6.3‰) were analyzed daily. Isotopic results are presented as the ratio of the heavier isotope to the lighter

isotope ($^{13}\text{C}/^{12}\text{C}$, $^{15}\text{N}/^{14}\text{N}$, $^{34}\text{S}/^{32}\text{S}$) and reported as δ values in parts per 1,000 or “per mil” (‰) relative to internationally defined standards for $\delta^{13}\text{C}$ (VPDB), $\delta^{15}\text{N}$ (AIR) and $\delta^{34}\text{S}$ (VCDT). The analytical error for both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurements was determined to be $\pm 0.2\text{‰}$ (1σ) or better, and $\pm 0.5\text{‰}$ for $\delta^{34}\text{S}$, based upon the reproducibility of isotopic measurements of internal and international standards.

4.3 Results and Discussion

The isotopic results and sample information are presented in Tables 4.S1 and 4.S2. The majority of the humans (75 out of 83) and animals (31 out of 36) produced good quality collagen with C:N between 2.9-3.6 (DeNiro, 1985; van Klinken, 1999). However, we were only able to obtain enough collagen for $\delta^{34}\text{S}$ measurements from 20 humans and 12 animals, but this still reflects the largest number of $\delta^{34}\text{S}$ values published for a Chinese archaeological site to date. All the $\delta^{34}\text{S}$ results had C:S and N:S results within the acceptable limits (C:S ratio of 600 ± 300 and N:S ratio of 200 ± 100) (Nehlich and Richards, 2009).

4.3.1 Faunal diet and animal husbandry practices at Nancheng

The carbon and nitrogen isotopic results of the fauna were variable with large ranges observed for both the $\delta^{13}\text{C}$ (-21.3‰ to -5.8‰) and $\delta^{15}\text{N}$ (2.8‰ to 8.3‰) values, and this is evidence of different diets and that different animal husbandry strategies were employed at the site (Figure 4.2a). When the mean values were plotted, a strong linear correlation was found ($R^2 = 0.89$) for all species that spanned the range between C_3 and C_4 diets (Figure 4.2b). In addition, the $\delta^{34}\text{S}$ results of the fauna are graphed in relation to the $\delta^{13}\text{C}$ (Figure 4.3a) and $\delta^{15}\text{N}$ (Figure 4.3b) values. Unfortunately, only 12 specimens produced enough collagen for $\delta^{34}\text{S}$ analysis, but interesting patterns were still detected. The $\delta^{34}\text{S}$ values ranged from 2.5‰ to 12.8‰ , demonstrating significant amounts of variation in the bioavailable environmental sulfur and also suggesting variable animal husbandry strategies.

The two dogs had an average value of -8.0‰ for $\delta^{13}\text{C}$, 7.3‰ for $\delta^{15}\text{N}$, and 7.5‰ for $\delta^{34}\text{S}$. The carbon results suggest a predominately C_4 diet of millets. The high nitrogen values are near but below the humans suggesting a diet with a possible inclusion of human refuse. The

sulfur values are nearly identical to the humans which also supports the likelihood of overlapping diets (Figures 4.3a,b), and this is a common finding for isotopic studies from north China (e.g. Chen et al., 2012; Si, 2013) as well as other parts of the world (reviewed by Guiry, 2012). Comparing our dog results with those of Hou et al. (2013) from Liuzhuang also finds very similar patterns (Figure 4.4a), and this is further evidence in support of our conclusions.

Pigs ($n = 3$) also had a predominately C_4 diet based on millets (mean \pm sd; $\delta^{13}C = -7.0 \pm 0.4\text{‰}$), and this agrees with previous results from north China (e.g. Pechenkina et al., 2005; Chen et al., 2012; Dai et al., in press). Their mean \pm sd $\delta^{15}N$ value of $7.8 \pm 0.4\text{‰}$ is the highest of all the species studied (Figure 4.2b), and these results combined with the carbon measurements suggests the pigs were kept in close proximity to the humans and likely consumed human leftovers and/or waste (feces). Only two pigs were measured for $\delta^{34}S$ (average value 7.6‰), and these were found to plot with the humans (Figures 3a,b). Nearly identical isotopic patterns are observed for the pigs at Nancheng and Liuzhuang (Figure 4.4a), and this reinforces the findings of Hou et al. (2013) that pigs during the Proto-Shang period were fed a relatively homogenous diet of mainly millet and human byproducts.

All cattle ($n = 5$) display a predominately C_4 diet (mean \pm sd; $\delta^{13}C = -8.3 \pm 1.8\text{‰}$) with $\delta^{15}N$ values (mean \pm sd; $7.3 \pm 1.0\text{‰}$) similar to the dogs and pigs. This suggests cattle were possibly fed in a similar manner as the dogs and pigs and were possibly kept close to the habitation site. In addition, our cattle measurements cluster with the isotopic results from Liuzhuang (Hou et al., 2013), and this is further evidence reinforcing this interpretation of shared animal husbandry strategies for Proto-Shang cattle, pigs, and dogs. However, four of the cows were analyzed for $\delta^{34}S$ values (mean \pm sd; $\delta^{34}S = 5.9 \pm 3.4\text{‰}$), and two groups were found; one with high $\delta^{34}S$ values (8.6‰ and 9.0‰) and one with low $\delta^{34}S$ values (2.5‰ and 3.3‰). The two cows with the high results plot just above the pigs in terms of $\delta^{34}S$ (Figures 4.3a,b) which is suggestive of a similar diet but with a greater component of C_3 plants in the diet. Further, these two cows have quite high $\delta^{15}N$ values which could be evidence they consumed plants fertilized with manure (e.g. Commisso and Nelson, 2006; 2007; Bogaard et al., 2007; Szpak, 2014), but additional isotopic research on plants from the site is necessary to confirm this. In contrast, the two cows with the low $\delta^{34}S$ values are very different than the other animals, and this suggests they were fed or foddered in a distinct location in relation to the site or possibly

coming from an entirely different site. Additional $\delta^{34}\text{S}$ measurements on a larger number of cattle combined with other isotopic techniques such as hydrogen (e.g. Topalov et al., 2013) or strontium (e.g. Viner et al., 2010) are ongoing, and will provide more information on this in the future. Still, these results demonstrate the added benefit of combining sulfur with carbon and nitrogen stable isotope measurements to glean more information about animal husbandry practices.

The sheep/goats ($n = 13$) show a wide range of $\delta^{13}\text{C}$ (-16.4‰ to -6.4‰; mean \pm sd = -12.1 ± 2.6 ‰) and $\delta^{15}\text{N}$ (5.1‰ to 8.3‰; mean \pm sd = 6.2 ± 1.1 ‰) values (Figures 4.2a,b). Three sheep/goats were analyzed for $\delta^{34}\text{S}$ and had a mean \pm sd of 7.3 ± 0.9 ‰. The sheep/goats had predominately C_4 or mixed C_3/C_4 diets, and this suggests they were allowed to roam and graze at different locations near the site (Figures 4.2a,b). However, a single sheep/goat ($\delta^{13}\text{C} = -6.4$ ‰; $\delta^{15}\text{N} = 8.3$ ‰) had a highly ^{13}C -enriched $\delta^{13}\text{C}$ value that plots close to the pigs, suggesting this individual was likely cared for in or near the settlement and fed with significant amounts of millet. When the sheep/goats from the Liuzhuang site (Hou et al., 2013) are plotted with our results (Figure 4.4a), the same general pattern emerges confirming that the sheep/goats had a wide dietary diversity in terms of C_3 and C_4 plant resources, and this is additional evidence they could freely graze on or near sites during the Proto-Shang period.

The deer ($n = 5$) have the lowest $\delta^{13}\text{C}$ (mean \pm sd; -20.8 ± 0.5 ‰) and $\delta^{15}\text{N}$ (mean \pm sd; 3.4 ± 0.5 ‰) values, evidence they consumed exclusive C_3 diets and likely grazed in a closed forested habitat due to the canopy effect (France, 1996; Vera, 2000; Drucker et al., 2008). For $\delta^{34}\text{S}$, only a single deer could be analyzed, and it produced the highest result (12.8‰) which is a clear outlier from the other animals (Figure 4.3a,b). This supports the carbon and nitrogen isotopic evidence that the deer lived in a unique ecological habitat that was distinct from the domestic animals. In addition a single sika deer was analyzed, and it had distinctly different $\delta^{13}\text{C}$ (-16.2‰) and $\delta^{15}\text{N}$ (5.0‰) values which indicates it consumed a mixed C_3/C_4 diet, and thus likely lived closer to the site and grazed on the millet fields or was possibly kept as a pet. Deer with similar ^{13}C -enriched $\delta^{13}\text{C}$ values were also found at the contemporary site of Xinzhai in Henan Province, and were thought to have been possibly raised for the purposes of hunting by the elites of the society (Dai et al., in press).

4.3.2 Human diet at Nancheng

The human carbon and nitrogen results in relation to the mean values of the animals are plotted in Figure 4.2b. The $\delta^{13}\text{C}$ values for 74 of the 75 individuals (excluding M70) have a narrow range between -8.3‰ to -5.8‰ (mean \pm sd; $-6.8 \pm 0.4\text{‰}$). This reflects a diet predominately based on terrestrial C_4 plants and/or animals that fed on C_4 plants. These results agree with the archaeobotanical evidence from phytoliths, pollen, and plant floatation research as well as the historical references from oracle bone scripts that mention millets (foxtail millet (*Setaria italica*) and broomcorn millet (*Panicum milaceum*)) as the dominant crops in the north of China from the Neolithic to the Three Dynasties: Xia, Shang, Zhou (Keightley, 1978; Zhang et al., 2003; Crawford et al., 2005; Pechenkina et al., 2005; Zhao, 2005; Crawford, 2006; Chen, 2007; Lee et al., 2007; Wang et al., 2010). Therefore, the human diet C_4 signature at Nancheng was certainly derived from the consumption of these species of millets. Comparing our results with those of Hou et al. (2013) from the contemporary site of Liuzhuang (Figure 4.4b) reveals a nearly identical pattern of millet consumption, evidence that the Proto-Shang clan adopted the dietary traditions of the Central Plains area when they migrated from north China. The exception to this is individual M70, whom consumed a mixed C_3/C_4 diet ($\delta^{13}\text{C} = -14.9\text{‰}$).

The human $\delta^{15}\text{N}$ values ranged from 7.9‰ to 11.1‰ , with a mean \pm sd of $9.4 \pm 0.6\text{‰}$. In addition, the $\delta^{34}\text{S}$ results ranged from 5.5‰ to 8.8‰ (mean \pm sd; $7.0 \pm 0.8\text{‰}$), but only 20 individuals produced enough collagen for analysis. Examining Figure 4.2b, it is clear that pigs were the dominant source of animal protein for the Nancheng population since the humans plot directly above them (mean human-pig isotopic spacing = 0.2‰ for $\delta^{13}\text{C}$ and 1.6‰ for $\delta^{15}\text{N}$) although it is possible that cattle (mean human-cow isotopic spacing = 1.5‰ for $\delta^{13}\text{C}$ and 2.1‰ for $\delta^{15}\text{N}$) and dogs (mean human-dog isotopic spacing = 1.2‰ for $\delta^{13}\text{C}$ and 2.1‰ for $\delta^{15}\text{N}$) were also consumed to some extent. The variability in human $\delta^{15}\text{N}$ (3.2‰) represents approximately one trophic level indicating there were different degrees of domestic animal protein consumption in the population. Some individuals with low $\delta^{15}\text{N}$ values between $\sim 8\text{‰}$ - 9‰ , likely had a mostly plant based diet of millet, since the $\delta^{15}\text{N}$ values are nearly identical or slightly elevated compared to the pigs, cows, and dogs. In contrast, individuals with high $\delta^{15}\text{N}$ values such as M28 (11.1‰), consumed a significant amount of protein mainly from pigs.

The $\delta^{34}\text{S}$ results are further support the humans mainly consumed pigs and some cows (Figures 4.3a,b). However, a pair of cattle with lower $\delta^{34}\text{S}$ values compared to the other domestic animals and humans was unexpectedly found. Given that the trophic level shift for sulfur isotope ratios is about -1‰ (Nehlich, 2015), human $\delta^{34}\text{S}$ values should be slightly lower than the animals they consumed. Therefore, these $\delta^{34}\text{S}$ results suggest that some cattle might not have contributed any significant amounts of protein to the regular diets of the humans. Thus, it is possible these cattle with low $\delta^{34}\text{S}$ values were obtained from a foreign area and might have been used more for labor rather than consumed.

Interestingly, the isotopic results from both the Nancheng and Liuzhuang sites (Hou et al. 2013) suggest that humans did not consume sheep/goats in significant quantities compared to pigs (Figure 4.4b). The exception to this at Nancheng was sample M70, since it appears that the diet of this individual was based on sheep/goats or that he/she was a possible migrant to the site (see below). If the sheep/goats did not act as dietary staples, then this is possible evidence they were kept for their secondary products such as wool. Unfortunately, no detailed zooarchaeological analysis has been conducted at Nancheng which could provide more information on this possibility. However, this finding is not without precedent during this time period in China. At the relatively contemporary late Neolithic/Early Bronze Age sites of Taosi, Xinzhai, and Erlitou, an analysis of the mortality profiles of the sheep and goats determined that the kill-off patterns were strongly suggestive of herding strategies related to maximize wool production (Dai et al., 2014; Li et al., 2014). Further, an isotopic study focused on animal husbandry practices at Xinzhai confirmed that the human diet was centered on pigs and cattle and that sheep were mainly exploited for wool (Dai et al., in press).

Like the sheep/goats, the large isotopic spacing for carbon (14.0‰), nitrogen (6.0‰), and sulfur (5.8‰) for the deer strongly suggests that they were not a major source of animal protein for the human population at Nancheng (Figures 4.2b and 4.3a,b). Similar isotopic patterns were observed at the contemporary site of Xinzhai (Dai et al., in press), and at the somewhat earlier Late Longshan period (2200 – 1900 BC) site of Wadian (Chen et al., in press). Dai et al. (in press) proposed that the deer at Xinzhai might have been preferentially hunted for making tools and weapons given the large number of deer bone artifact recovered at the site, and this could also have been the case at Nancheng.

4.3.3 Linking diet with sex and age at Nancheng

To examine the possibility of sex related dietary variation, the $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ results of the confirmed males and females were compared in Table 4.1. A one-way ANOVA test found no significant differences for the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, but did find a significant difference between the $\delta^{34}\text{S}$ results of the males and females (Table 4.1). Given the small number of individuals, particularly females, that were measured for $\delta^{34}\text{S}$, we believe it is premature to equate any substantial meaning to this finding at the moment. However, the results are intriguing and suggest a possible important area of future research whereby some females might have traveled from different areas to Nancheng or had slightly different diets compared to the males. The fact that the males and the females of the overall population did not show significant differences in their $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values suggests the possibility that they had relatively equal access to food.

The isotopic results were also compared by age group in Figure 4.5a. A one-way ANOVA test found no significant differences in the $\delta^{15}\text{N}$ values, but the $\delta^{13}\text{C}$ values of the individuals aged between 40-50 years old were found to be significantly elevated compared to the younger age groups (Table 4.2). In addition, when these results were further classified by sex between younger (less than 40 years old) and older (greater than 40 years of age) individuals, significant differences in $\delta^{13}\text{C}$ values were found for the males (one way ANOVA, $p < 0.001$), but not for the females (one way ANOVA, $p = 0.706$) (Figure 4.5b). This finding that older males have elevated $\delta^{13}\text{C}$ values (mean \pm sd, $-7.3 \pm 0.5\text{‰}$) compared to the younger males (mean \pm sd, $-6.6 \pm 0.3\text{‰}$) could possibly be the result of their elevated status within the community where they were allowed or given a more variable diet, possibly more beef since the cattle have lower $\delta^{13}\text{C}$ values than the normal dietary staple of the pigs (Figure 4.2b). This possibility would be in agreement with the historical texts written during later periods. However, we must caution that this is speculative, and we find no evidence that the older individuals, males or females, were consuming more animal protein in their diets compared to the younger members of the population. It is also entirely possible that these differences in $\delta^{13}\text{C}$ values have nothing to do with status and might reflect division of labor where the older males at Nancheng consumed a slightly different diet of more C_3 based foods from activities such as gathering wild plants or catching small game around the settlement site. Whatever

the reason, it is difficult to determine or further speculate on a more precise cause for these isotopic differences between the young and old males, but we believe this is an area of important future research for Proto-Shang sites.

4.3.4 Linking diet, burial customs, and social status at Nancheng

Here we examine the possibility that individual dietary differences might be related to social status as inferred by the burial customs at the Nancheng site. Burial customs and the type and quality of graves goods can reveal important characteristics about a past culture including customs, religion, and status (Service, 1975; Brown, 1981; Danforth, 1999; Scarre, 2005; Curet and Pestle, 2010). At Nancheng, the majority of the burials analyzed ($n = 70$) were oriented from west to east in a supine position, but five graves were aligned in a north to south direction (M46, M51, M70, M76 and M78), and two of these individuals (M51, M70) were the only ones to be buried in a flexed position (Table 4.S1). These results are plotted in Figure 4.6, and it can be seen that there are no differences between the groups buried either west to east or north to south in the supine position. However, the two individuals that were buried in a flexed position have the lowest $\delta^{13}\text{C}$ values and stand out from the rest of the population at Nancheng.

Comparing our results to those of Hou et al. (2013) from Liuzhuang, similarities emerge, as three individuals are also seen with lower $\delta^{13}\text{C}$ values and variable $\delta^{15}\text{N}$ values (Figure 4.4b); although M51 now overlaps with the main body of both populations. With these different diets and unique burial positions, it is possible that these two individuals were migrants to this Proto-Shang community. As a potential test of this hypothesis, we measured the bone collagen of M70 for $\delta^{34}\text{S}$ (M51 did not yield enough additional collagen for $\delta^{34}\text{S}$ analysis). However, the $\delta^{34}\text{S}$ result of M70 (while the highest, 8.8‰) was near the other humans (Figures 4.3a,b) and within the range of the domestic animals ($8.2 \pm 2.6\text{‰}$). This suggests that this individual was a local resident rather than an immigrant to the community, but it is possible that he/she was an immigrant from an area with a similar geological $\delta^{34}\text{S}$ signature as the Nancheng site. Unfortunately, as there is no sex or age information for M70, and as no grave goods were found, it is difficult to speculate on why these differences are observed. Whatever the reason, it is clear that M70 was a unique individual to this community, and this evidence combined with the isotopic outliers and different type of burial customs (stone coffin,

wooden coffin, earthen shaft pit) at Liuzhuang (Hou et al. 2013), provide support to the theory that the Proto-Shang people were a collection of different groups or chiefdoms with different subsistence strategies rather than a single political or ethnic group (Zhu, 2007; Wang, 2011). Additional work is required using different isotopic measurements (oxygen, hydrogen, strontium, etc.) combined with ancient DNA analysis to determine if these observed outliers found at Nancheng and Liuzhuang represent local or migrant individuals, and this is an area of active research.

In order to investigate the relationship between diet and status, individuals were divided into three groups based on the type of grave goods recovered: high status (jade, calcite, shells; $n = 8$), medium status (only pottery; $n = 28$), and low status (no grave goods; $n = 39$) (Figure 4.7). High status individuals such as M3 and M15, buried with shells and jade, were hypothesized to have more animal protein in their diets compared to the low status individuals based on the accounts of historical sources from later periods (see above). However, the data do not support this hypothesis as a one way ANOVA test found no significant differences between the $\delta^{13}\text{C}$ ($p = 0.463$) or the $\delta^{15}\text{N}$ ($p = 0.913$) results, suggesting that dietary variations were not related to wealth (as determined by the type of grave goods) and social status during the Proto-Shang period at Nancheng. In fact the highest $\delta^{15}\text{N}$ value (11.1‰) was found for M28, an adult male buried without grave goods. This finding (or lack thereof) is still important to Chinese history as it is possible evidence that the dietary differences associated with social hierarchy during the Shang and Zhou Dynasties had yet to be established during the Proto-Shang period.

While diet was not linked to status using grave goods, it is noteworthy that the low status individuals presented a broader range of $\delta^{13}\text{C}$ ($-7.1 \pm 1.4\text{‰}$) and $\delta^{15}\text{N}$ values ($9.4 \pm 0.7\text{‰}$) compared to the high ($\delta^{13}\text{C} = -6.7 \pm 0.3\text{‰}$; $\delta^{15}\text{N} = 9.5 \pm 0.3\text{‰}$) and medium status ($\delta^{13}\text{C} = -6.9 \pm 0.4\text{‰}$; $\delta^{15}\text{N} = 9.4 \pm 0.4\text{‰}$) individuals (Figure 4.7). Similar trends have also been observed at other sites. For instance, at Wetwang Slack in East Yorkshire, UK, Jay and Richards (2006) found no distinctions between status and diet, but the $\delta^{15}\text{N}$ values of the “poor” (i.e. the group marked as “no barrow and no grave goods”) showed a larger range than the “wealthy” (such as the “chariot burials” and the “barrows and grave goods”) group. We interpret the narrow isotopic ranges observed for the high and medium status individuals at Nancheng as possibly reflecting more stable access to food resources and a more shared or

similar subsistence pattern, whereas, the low status individuals might have had a more varied diet depending on their different means of livelihood.

4.4 Conclusions

Here we used a trio of isotopic measurements to examine dietary patterns at the Proto-Shang cemetery site of Nancheng and used these results to investigate social status and complexity as well as animal husbandry practices. The majority of the population had a C₄ diet based on millets, but a single individual (M70) was found to have a mixed C₃/C₄ diet. The $\delta^{34}\text{S}$ analysis of M70 determined this individual was unlikely a migrant even though his/her burial orientation (north-south) and position (flexed) was different from the majority of burials identified during excavation at the site. A large range of human $\delta^{15}\text{N}$ results suggest that animal protein consumption was variable, but that it was centered on pigs and cattle and possibly dogs. The sheep/goats were not consumed in great amounts and were likely kept for their secondary products (e.g. wool), and this finding is similar to the isotopic results of Liuzhuang (Hou et al. 2013) and other sites from this period in north China. The exception to this was the M70 individual whom possibly had a diet based more on sheep/goats. While there was great diversity in the type and quality of grave goods recovered from the burials, no dietary differences were found to correlate with perceived social status. Also no link between diet and sex was found at the population level, but when the data were sorted by age and sex, the older males (> 40 years old) were found to have significantly lower $\delta^{13}\text{C}$ values compared to the younger males (< 40 years old). Thus, it appears that while the entire society as a whole likely had equal access to the dietary items of the community, older males were possibly given or allowed to eat more diverse diets such as cattle. However, the dietary social stratification discussed in the historical texts about the later Shang and Zhou periods is not observed at Nancheng which is possible evidence that these traditions had yet to be formally established during the Proto-Shang period. This study highlights the value of combining $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ measurements to examine diet, individual locality, social complexity, and animal husbandry patterns, and we hope it will spur additional research on Chinese archaeological collections.

4.5 Acknowledgements

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4.7 Figures

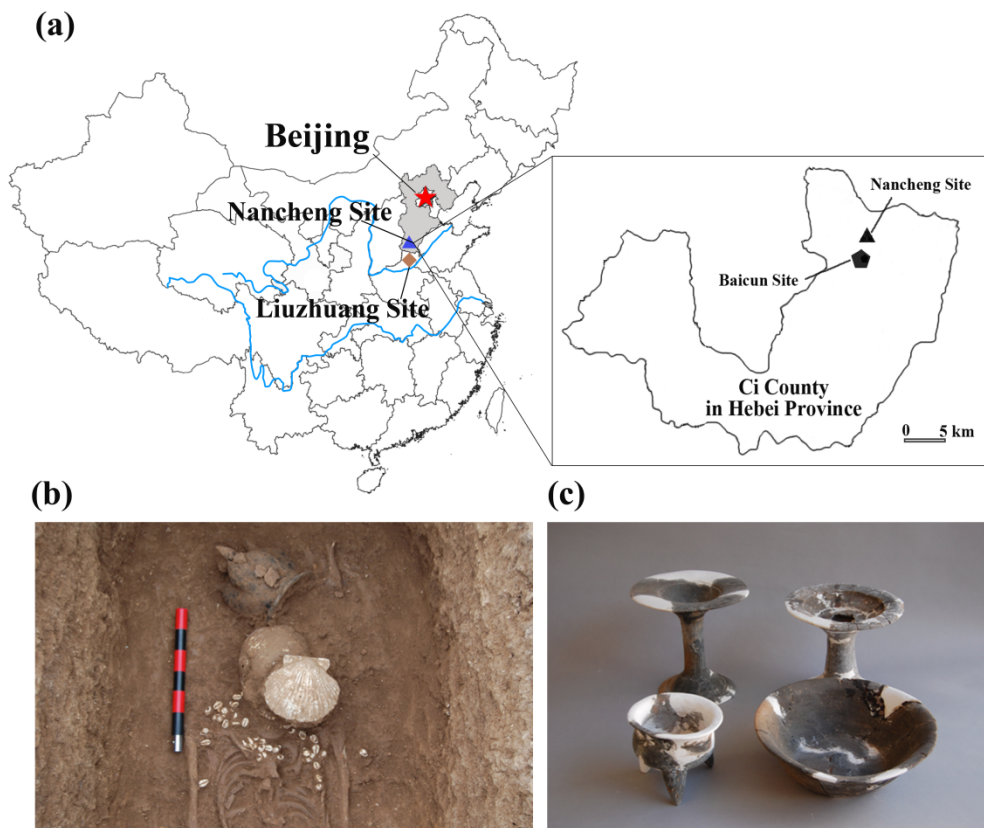


Figure 4.1. a) Map of mainland China showing the location of the Nancheng site in Hebei Province (shaded), the location of the Liuzhuang site in Henan Province, with an expanded section showing the locations of the Nancheng and Baicun sites in Ci County of Hebei Province. b) Picture of burial M3 showing that the head was covered with a large scallop shell “蚌” (Pectinidae) that was possible part of a cowry “贝” (Cypraeidae) necklace. c) Picture of typical pottery recovered from the burials.

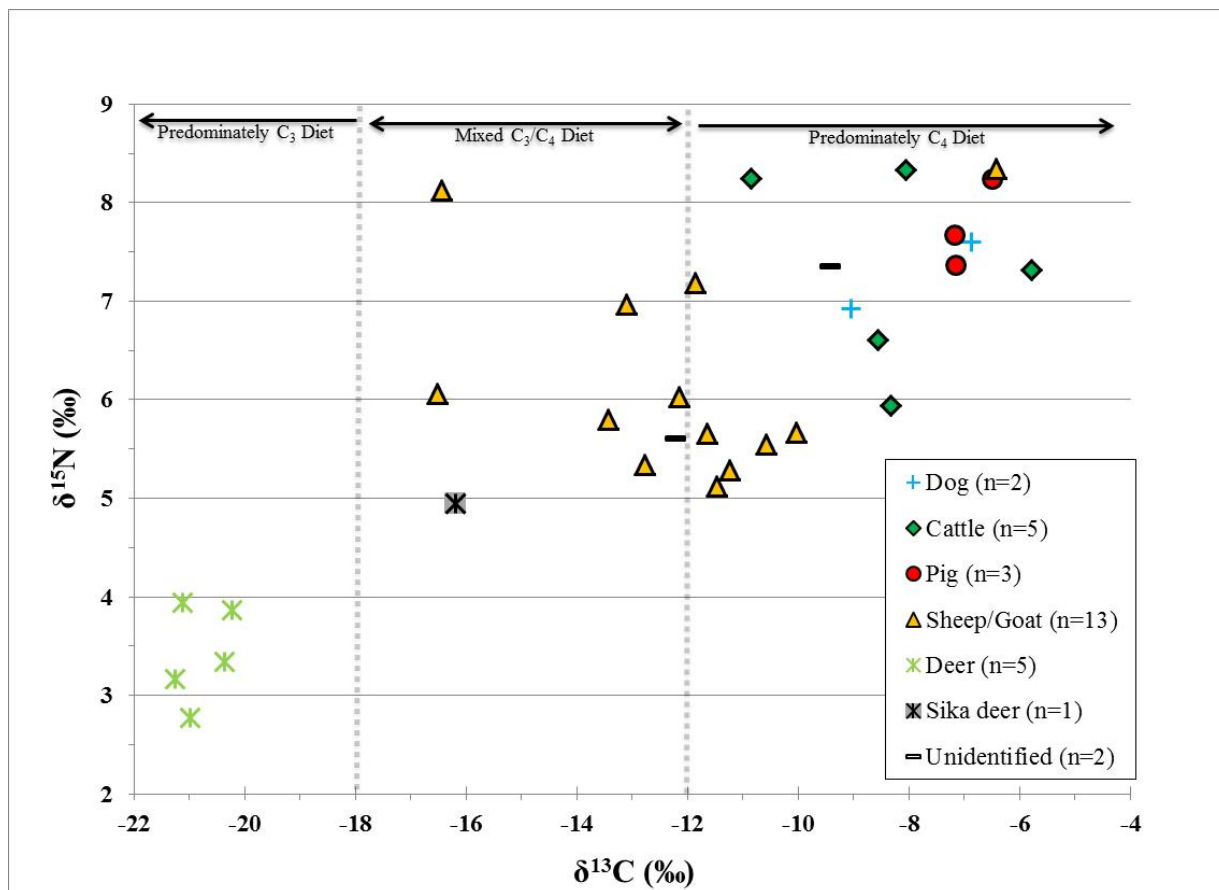


Figure 4.2a. $\delta^{13}C$ and $\delta^{15}N$ animal results from the Nancheng and Baicun sites in Hebei Province, China. Note: Measurements $> -12\text{‰}$ reflect a predominately C_4 diet, values between -12‰ to -18‰ indicate a mixed C_3/C_4 diet, and values < -18 reflect a predominately C_3 diet in China (Pechenkina et al., 2005; Barton et al., 2009).

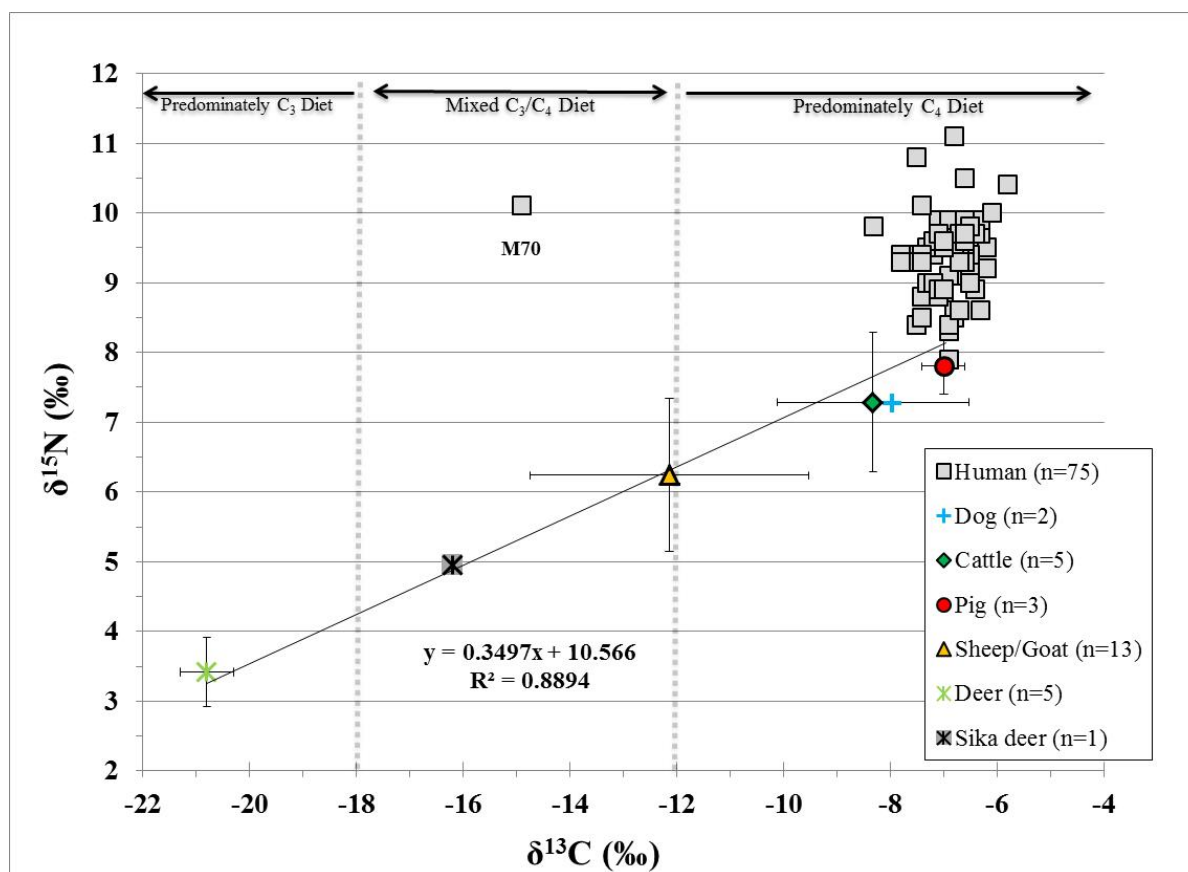


Figure 4.2b. Human and the mean \pm SD animal $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from the Nancheng and Baicun sites in Hebei Province, China. A strong linear correlation ($R^2 = 0.89$) in the mean animal results is observed between the C_3 and C_4 environments. Note: Measurements $> -12\text{‰}$ reflect a predominately C_4 diet, values between -12‰ to -18‰ indicate a mixed C_3/C_4 diet, and values < -18 reflect a predominately C_3 diet in China (Pechenkina et al., 2005; Barton et al., 2009).

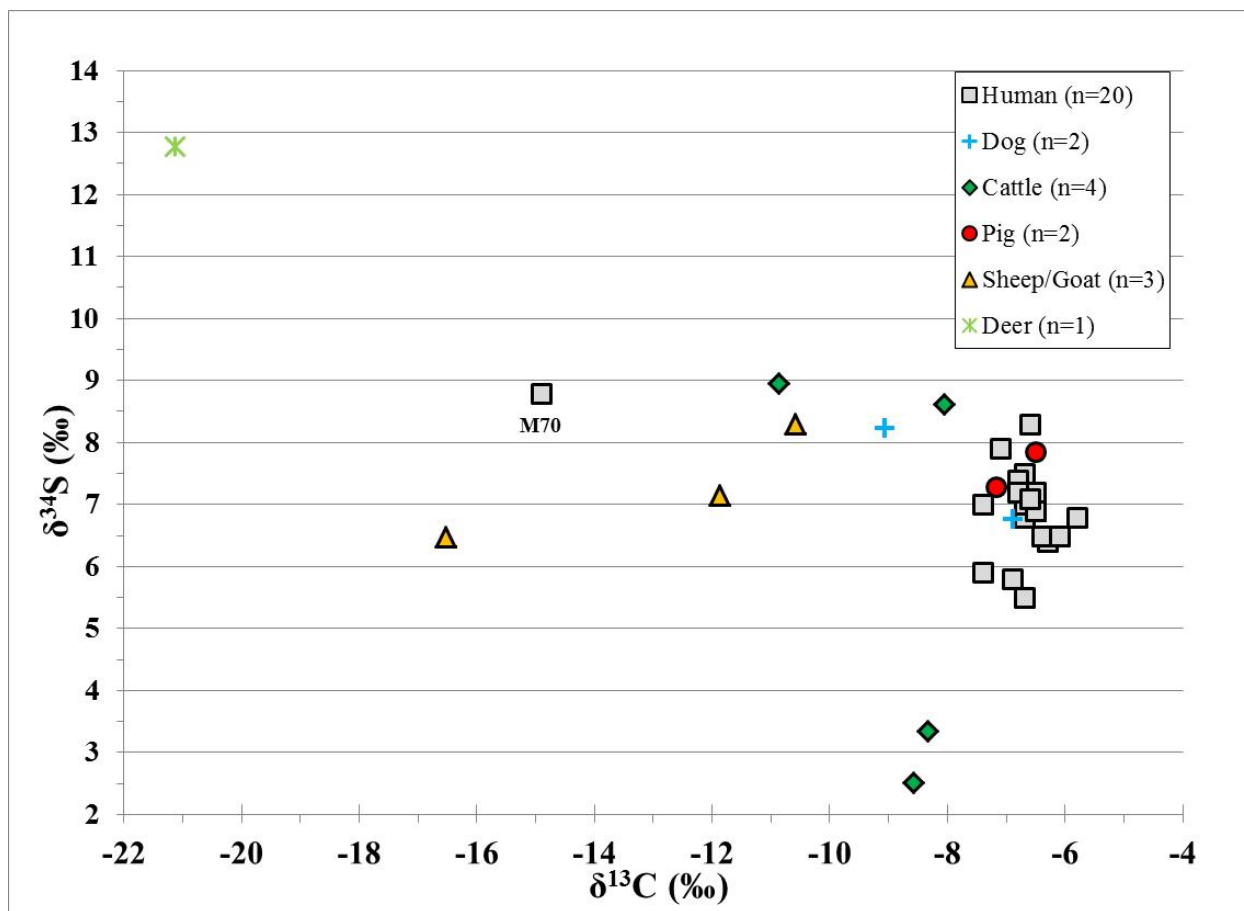


Figure 4.3a. Human and animal $\delta^{34}\text{S}$ and $\delta^{13}\text{C}$ results from the Nancheng and Baicun sites in Hebei Province, China.

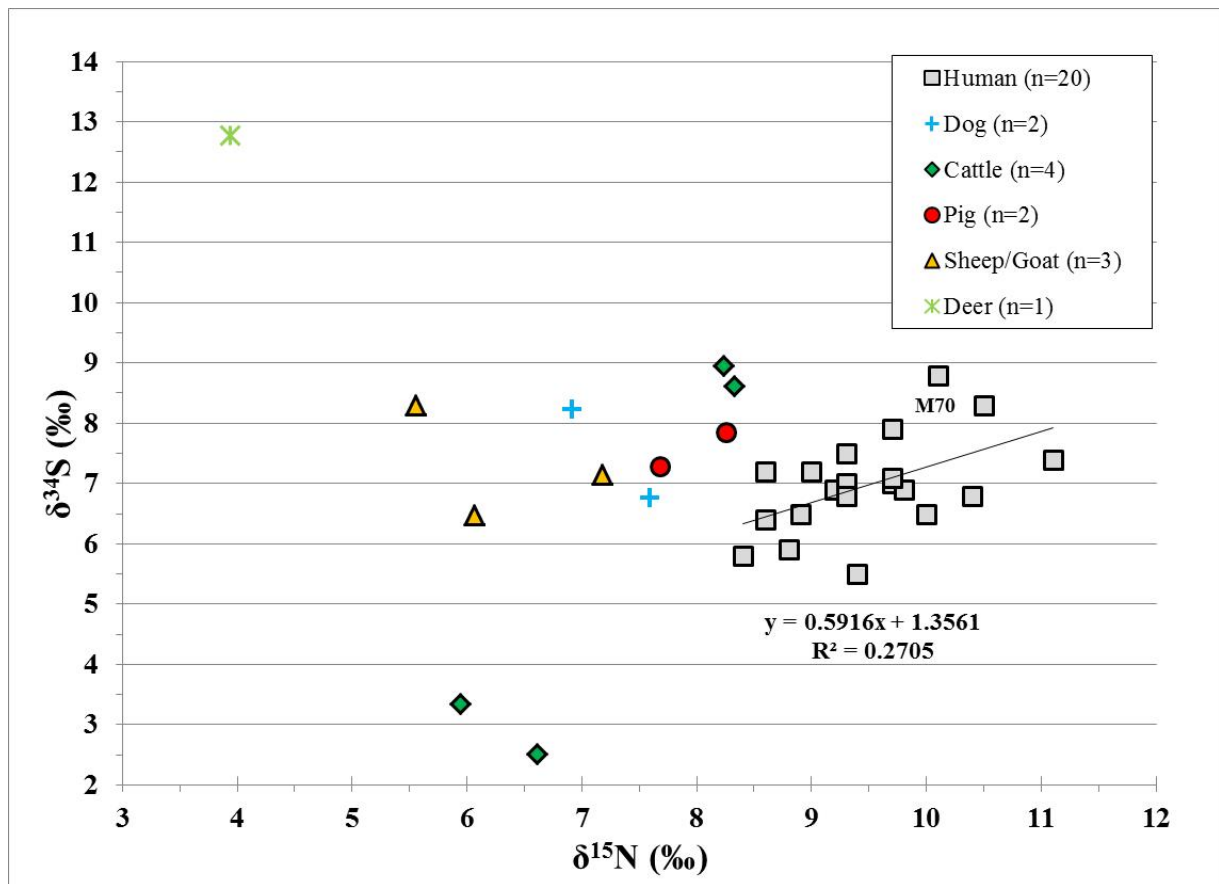


Figure 4.3b. Human and animal $\delta^{34}\text{S}$ and $\delta^{15}\text{N}$ results from the Nancheng and Baicun sites in Hebei Province, China.

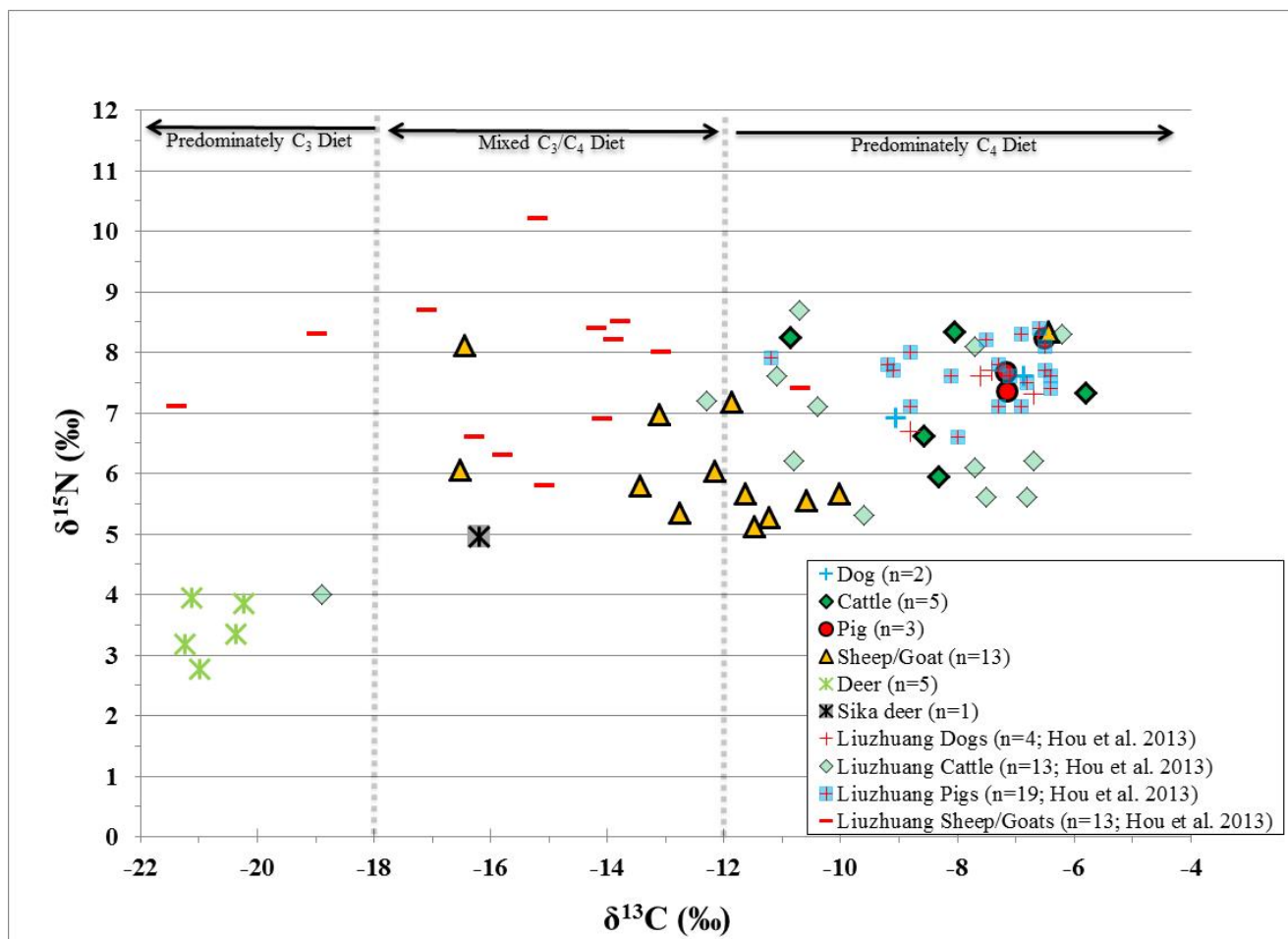


Figure 4.4a. Plot of the animal $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results of Hou et al. (2013) with the animal $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from the Baicun site in Hebei Province, China.

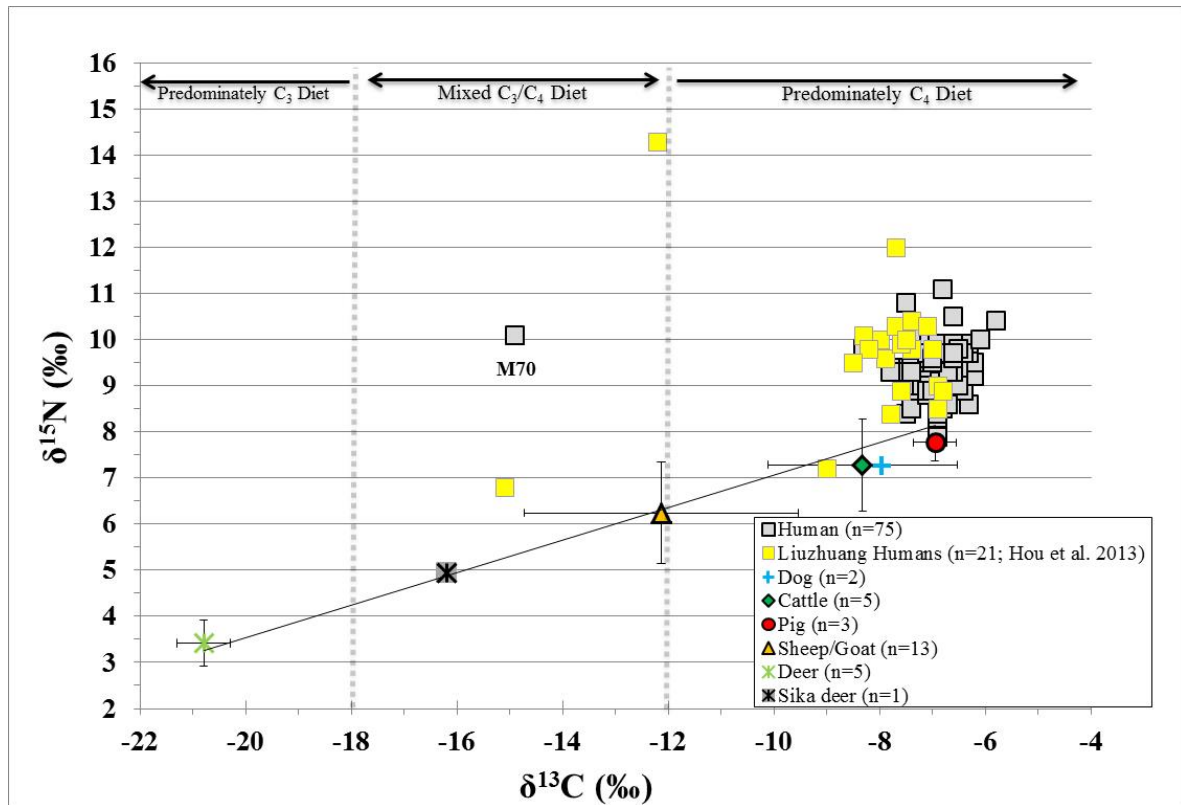


Figure 4.4b. Comparing the human $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results of Hou et al. (2013) with the human and mean \pm SD animal $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from the Nancheng and Baicun sites in Hebei Province, China. The similarities in the isotopic results between the two sites suggest that pigs were the primary source of dietary animal protein during the Proto-Shang period. However, note the three individuals with significantly different mixed C₃/C₄ diets that could suggest consumption of more sheep/goats and/or that they were migrants from other communities.

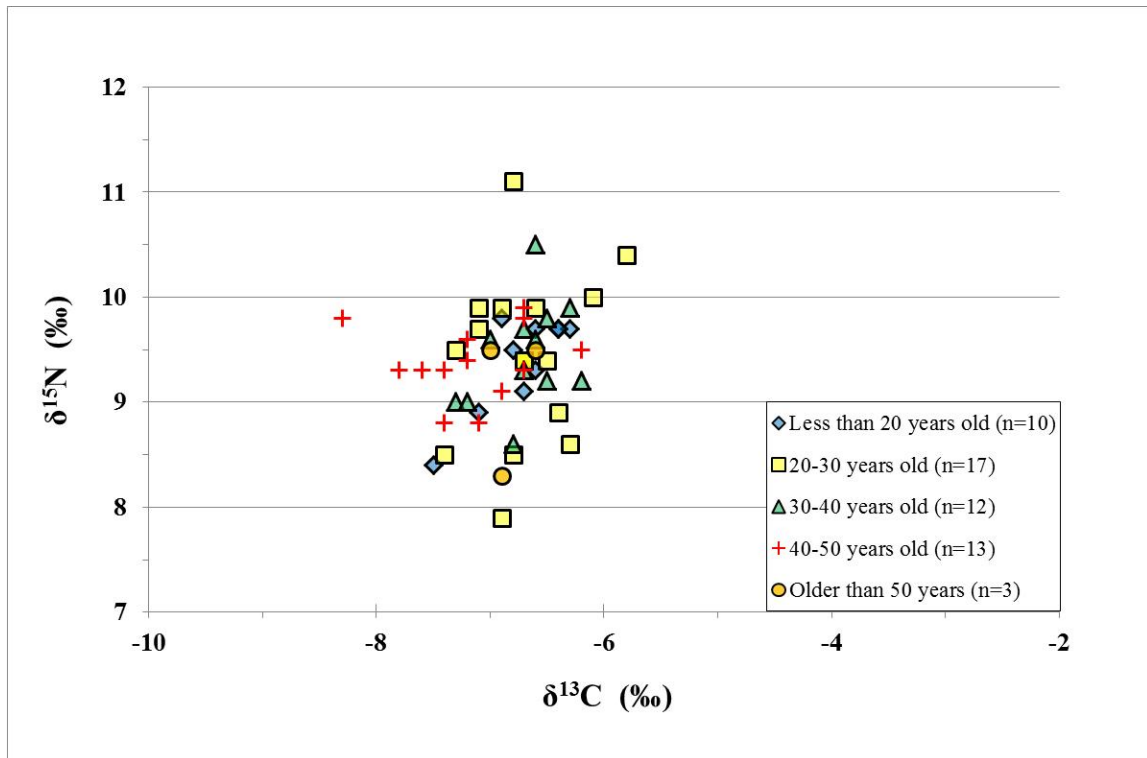


Figure 4.5a. Human $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results plotted in relation to the estimated age from the site of Nancheng, Hebei Province, China. No significant differences are observed in the $\delta^{15}\text{N}$ values, but individuals aged between 40-50 years old were found to be significantly elevated in $\delta^{13}\text{C}$ compared to the younger age group (Table 4.2).

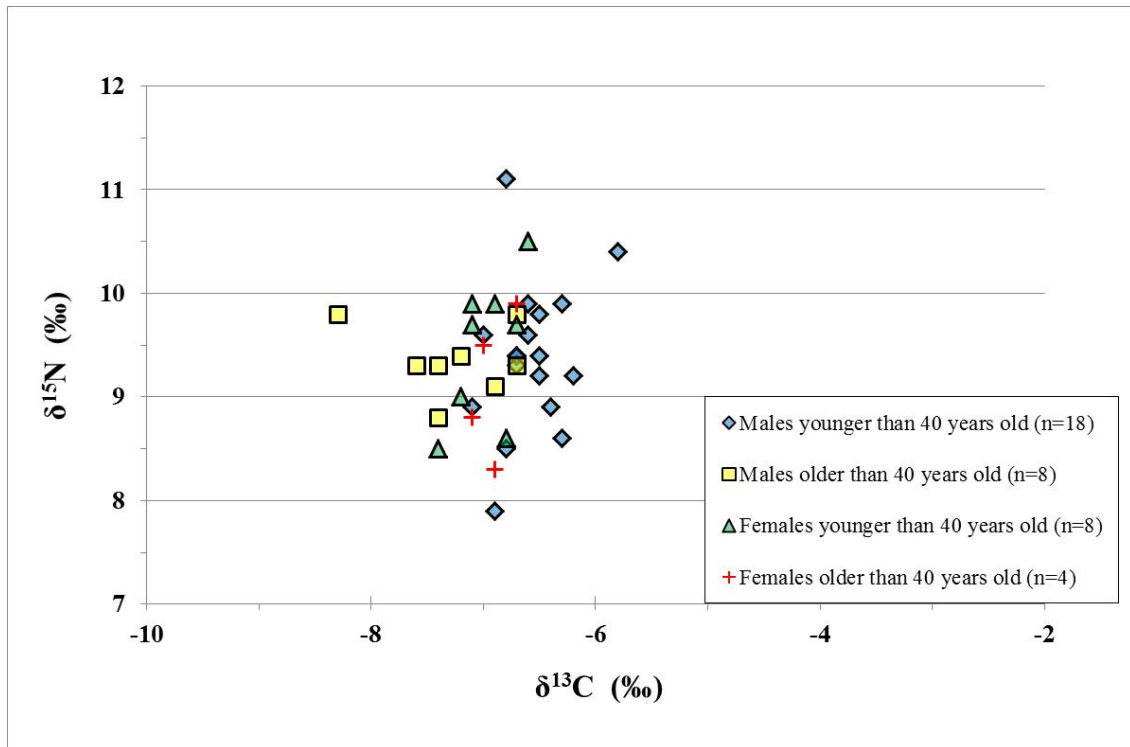


Figure 4.5b. Human $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results plotted in relation to sex and sorted by younger (less than 40 years old) and older (greater than 40 years of age) individuals at the site of Nancheng, Hebei Province, China. Significant differences in $\delta^{13}\text{C}$ values were found between the younger and older males (one way ANOVA, $p < 0.001$), but not between the younger and older females (one way ANOVA, $p = 0.706$).

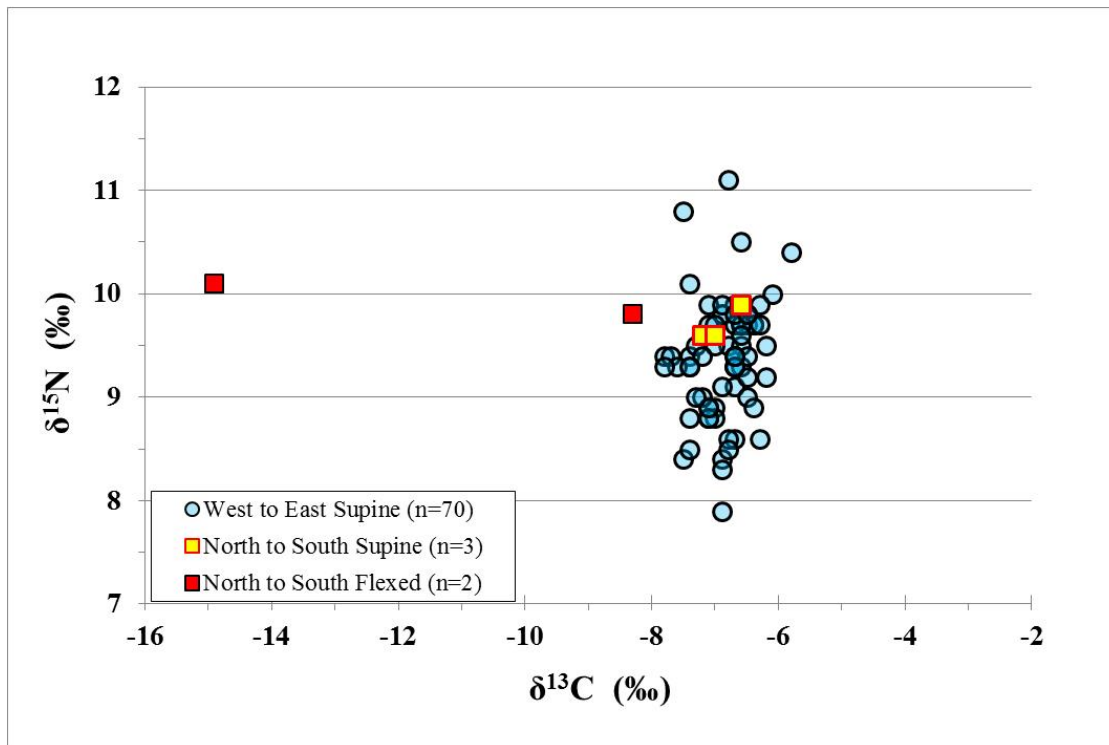


Figure 4.6. Human $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results plotted in relation to burial direction and position at Nancheng, Hebei Province, China.

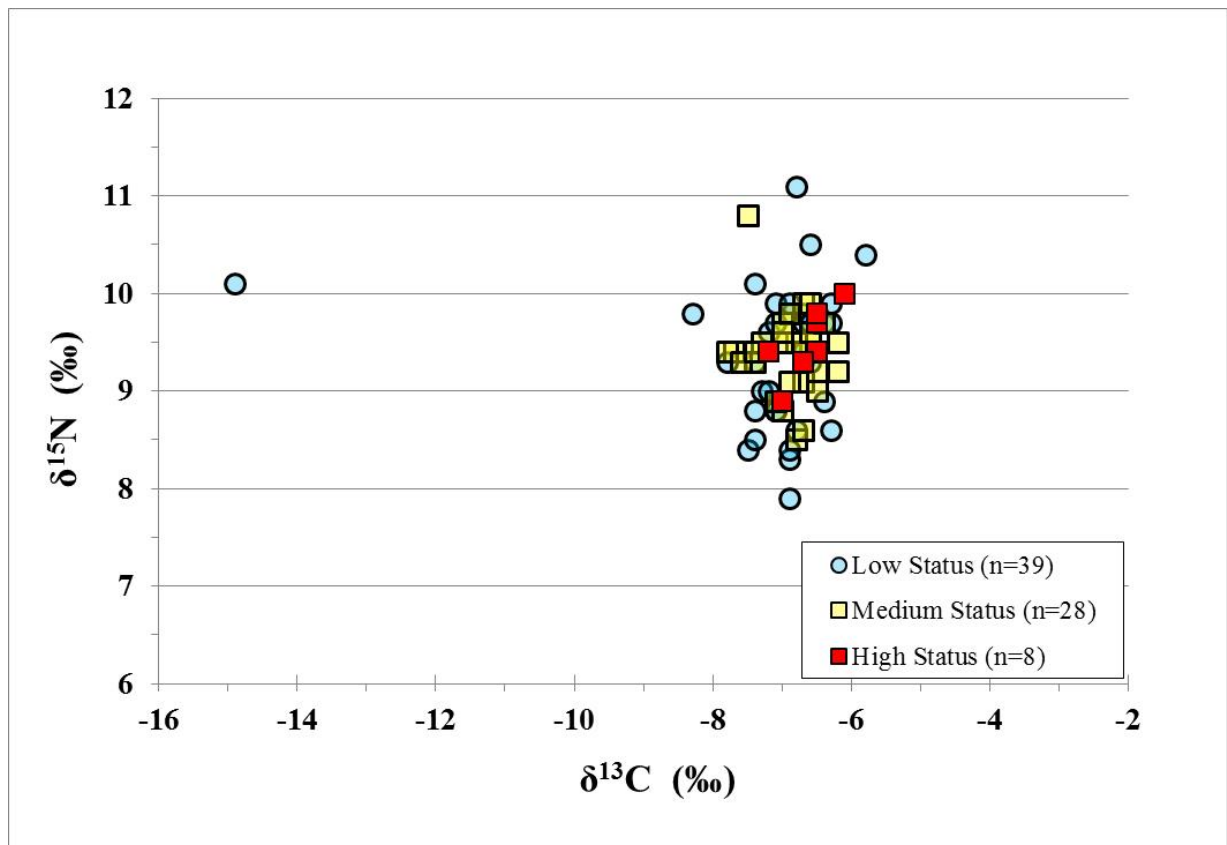


Figure 4.7. Human $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results plotted in relation to status based on the type of associated grave goods recovered from the burials at Nancheng, Hebei Province, China. A one way ANOVA test found no significant differences between the $\delta^{13}\text{C}$ ($p = 0.463$) or the $\delta^{15}\text{N}$ ($p = 0.913$) results, suggesting that dietary variations were not related to wealth (as determined by the type of grave goods).

4.8 Tables

Table 4.1. Mean \pm SD isotopic results classified by sex. The results of a one way ANOVA tests found no significant differences between the males and females for the $\delta^{13}\text{C}$ ($p = 0.41$) and $\delta^{15}\text{N}$ ($p = 0.93$) values, but did find a significant difference for the $\delta^{34}\text{S}$ ($p = 0.03$) results.

	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	$\delta^{34}\text{S}$ (‰)
Male	-6.8 \pm 0.5 (N=27)	9.4 \pm 0.6 (N=27)	6.7 \pm 0.7 (N=9)
Female	-7.0 \pm 0.2 (N=12)	9.4 \pm 0.7 (N=12)	7.6 \pm 0.6 (N=4)

Table 4.2. One way ANOVA test comparing the 40-50 year old humans with the individuals from the other age groups from Nancheng. p values which are significant are in bold.

Age Groups	N	Mean $\delta^{13}\text{C}$ (‰)	Standard Deviation	p value	Mean $\delta^{15}\text{N}$ (‰)	Standard Deviation	p value
> 20 years old	10	-6.7	0.4	0.017	9.4	0.5	0.49
20-30 years old	17	-6.7	0.4	0.005	9.4	0.8	0.37
30-40 years old	12	-6.7	0.3	0.008	9.5	0.5	0.40
40-50 years old	13	-7.2	0.6	--	9.4	0.3	--
Older than 50 years	3	-6.8	0.2	0.219	9.1	0.7	1.03

4.9 Supplementary Information

Table 4.3S1. Isotopic results and sample information for the Proto-Shang humans from the Nancheng cemetery site, Hebei Province, China

Sample	Sex	Bone	Age	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	$\delta^{34}\text{S}$ (‰)	%C	%N	%S	C/N	C/S	N/S	Burial Orientation and Position	Grave Goods	Perceived Social Status Based on Grave Good Type
M80	Female?	Humerus	20±	-6.1	10.0	6.5	43.1	15.7	0.27	3.2	430	134	W-E, Supine	Calcite	High
M40	Male	Rib	25-30	-6.5	9.4	--	44.0	15.3	--	3.4	--	--	W-E, Supine	Jade	High
M89	?	Rib	?	-7.0	8.9	--	39.8	14.3	--	3.2	--	--	W-E, Supine	Jade	High
M66	?	Rib	?	-6.7	9.3	6.8	42.6	15.5	0.26	3.2	438	136	W-E, Supine	Jade, Pottery (Li 鬲)	High
M15	Male	Tibia	45±	-7.2	9.4	--	43.8	15.2	--	3.4	--	--	W-E, Supine	Jade, Scallop shell 蚌 (<i>Pectinidae</i>), Pottery (Ding 鼎, Pot 盆, Chalice 豆)	High
M87	?	Tibia	?	-6.5	9.8	6.9	42.8	15.4	0.26	3.3	438	135	W-E, Supine	Scallop shell 蚌 (<i>Pectinidae</i>)	High
M3	?	Humerus	?	-6.5	9.7	--	45.2	15.6	--	3.4	--	--	W-E, Supine	Scallop shell 蚌 (<i>Pectinidae</i>), Sea snail shells 贝 (<i>Cypraeidae</i>), Pottery (Li 鬲)	High
M12	Male	Femur	30±	-6.7	9.3	7.5	44.7	15.8	0.21	3.3	562	170	W-E, Supine	Sea snail shells 贝 (<i>Cypraeidae</i>)	High
M29	Male?	Rib	Adult	-7.0	9.7	--	44.4	15.5	--	3.4	--	--	W-E, Supine	Pottery (Ding 鼎)	Medium
M32	Male?	Humerus	45-50	-6.2	9.5	--	43.8	15	--	3.4	--	--	W-E, Supine	Pottery (Li 鬲, Chalice 豆)	Medium
M19	Male	Rib	Adult	-7.7	9.4	--	41.3	13.8	--	3.5	--	--	W-E, Supine	Pottery (Ding 鼎)	Medium

M23	Male	Rib	35-40	-6.5	9.2	6.9	43.6	15.6	0.24	3.3	487	149	W-E, Supine	Pottery (Ding 鼎)	Medium
M45	Male	Tibia	40-45	-7.6	9.3	--	43.3	14.4	--	3.5	--	--	W-E, Supine	Pottery (Ding 鼎)	Medium
M78	Male	Rib	35-40	-7.0	9.6	--	40.8	14.5	--	3.3	--	--	N-S, Supine	Pottery (Ding 鼎, Li 鬲)	Medium
M7	Male	Tibia	45±	-6.9	9.1	--	44.4	15.6	--	3.3	--	--	W-E, Supine	Pottery (Ding 鼎, Pot 盆)	Medium
M72	Male	Rib	30±	-6.6	9.6	--	39.1	14.2	--	3.2	--	--	W-E, Supine	Pottery (Ding 鼎, Chalice 豆)	Medium
M33	Male	Rib	25-30	-6.8	8.5	--	40.2	13.8	--	3.4	--	--	W-E, Supine	Pottery (Jar 罐)	Medium
M34	Male	Tibia	40-45	-7.4	9.3	7.0	45.1	15.4	0.24	3.4	505	148	W-E, Supine	Pottery (Li 鬲)	Medium
M76	Male	Rib	20±	-6.6	9.9	--	43.3	15.7	--	3.2	--	--	N-S, Supine	Pottery (Li 鬲)	Medium
M21	Male	Rib	35±	-6.2	9.2	--	43.7	15.6	--	3.3	--	--	W-E, Supine	Pottery (Li 鬲, Pot 盆, Chalice 豆)	Medium
M54	Male	Humerus	25±	-6.7	9.4	--	42.4	15.0	--	3.3	--	--	W-E, Supine	Pottery (Urn 瓮)	Medium
M36	Female?	Rib	25-30	-7.3	9.5	--	42.8	14.4	--	3.5	--	--	W-E, Supine	Pottery (Ding 鼎)	Medium
M47	Female?	Rib	>60	-6.6	9.5	--	44.2	15.0	--	3.4	--	--	W-E, Supine	Pottery (Ding 鼎)	Medium
M10	Female	Tibia	45±	-6.7	9.9	--	44.2	15.5	--	3.3	--	--	W-E, Supine	Pottery (Ding 鼎)	Medium
M69	Female	Humerus	55-60	-7.0	9.5	--	43.0	15.1	--	3.3	--	--	W-E, Supine	Pottery (Ding 鼎, Pot 盆, Chalice 豆)	Medium
M5	?	Rib	Adolescent	-6.7	9.1	--	44.7	15.6	--	3.4	--	--	W-E, Supine	Pottery (Ding 鼎)	Medium
M73	?	Tibia	Adolescent	-6.4	9.7	--	44.0	15.7	--	3.3	--	--	W-E, Supine	Pottery (Ding 鼎)	Medium
M38	?	Rib	Adult	-7.8	9.4	--	42.3	13.7	--	3.6	--	--	W-E, Supine	Pottery (Ding 鼎, Chalice 豆)	Medium
M30	?	Rib	?	-6.9	9.8	--	44.2	15.0	--	3.4	--	--	W-E, Supine	Pottery (Jar 罐)	Medium

M39	?	Tibia	?	-6.5	9.0	7.2	44.2	15.3	0.28	3.4	423	126	W-E, Supine	Pottery (Li 鬲)	Medium
M62	?	Rib	?	-7.4	9.4	--	43.5	15.5	--	3.3	--	--	W-E, Supine	Pottery (Li 鬲)	Medium
M64	?	Rib	Adolescent	-6.8	9.5	--	42.3	15.3	--	3.2	--	--	W-E, Supine	Pottery (Li 鬲)	Medium
M86	?	Tibia	?	-7.1	8.9	--	42.0	15.1	--	3.3	--	--	W-E, Supine	Pottery (Li 鬲)	Medium
M91	?	Tibia	?	-7.5	10.8	--	39.6	13.3	--	3.5	--	--	W-E, Supine	Pottery (Li 鬲)	Medium
M42	?	Rib	?	-7.0	8.8	--	41.0	13.9	--	3.4	--	--	W-E, Supine	Pottery (Li 鬲, Chalice 豆)	Medium
M88	?	Tibia	?	-6.7	8.6	--	43.2	15.6	--	3.2	--	--	W-E, Supine	Pottery (Li 鬲, Jar 罐)	Medium
M61	Male?	Humerus	45-50	-7.8	9.3	--	41.1	14.4	--	3.3	--	--	W-E, Supine	None	Low
M74	Male?	Tibia	30-35	-7.3	9.0	--	41.4	15.1	--	3.2	--	--	W-E, Supine	None	Low
M2	Male	Rib	40±	-6.7	9.8	--	44.4	15.5	--	3.4	--	--	W-E, Supine	None	Low
M14	Male	Rib	25-30	-6.3	8.6	6.4	44.2	15.7	0.24	3.3	485	148	W-E, Supine	None	Low
M17	Male	Rib	20±	-6.4	8.9	6.5	43.6	15.3	0.23	3.3	512	154	W-E, Supine	None	Low
M27	Male	Tibia	15-20	-7.1	8.9	--	44.7	15.9	--	3.3	--	--	W-E, Supine	None	Low
M28	Male	Rib	20±	-6.8	11.1	7.4	45.0	15.8	0.22	3.3	551	166	W-E, Supine	None	Low
M44	Male	Tibia	20-25	-6.9	7.9	--	36.6	12.4	--	3.5	--	--	W-E, Supine	None	Low
M49	Male	Rib	40±	-6.7	9.3	--	43.7	14.9	--	3.4	--	--	W-E, Supine	None	Low
M51	Male	Tibia	40±	-8.3	9.8	--	40.2	13.0	--	3.6	--	--	N-S, Flexed	None	Low
M52	Male	Rib	30±	-6.3	9.9	--	40.2	13.7	--	3.4	--	--	W-E, Supine	None	Low

M53	Male	Rib	30±	-6.5	9.8	--	42.2	14.4	--	3.4	--	--	W-E, Supine	None	Low
M57	Male	Rib	20±	-6.7	9.4	5.5	43.7	15.9	0.27	3.2	440	137	W-E, Supine	None	Low
M58	Male	Tibia	40±	-7.4	8.8	5.9	42.8	15.4	0.26	3.3	440	135	W-E, Supine	None	Low
M75	Male	Tibia	25±	-5.8	10.4	6.8	43.6	15.9	0.21	3.2	563	176	W-E, Supine	None	Low
M18	Female?	Humerus	15-20	-6.6	9.7	--	44.3	15.7	--	3.3	--	--	W-E, Supine	None	Low
M50	Female?	Tibia	20±	-6.7	9.4	--	42.2	14.3	--	3.4	--	--	W-E, Supine	None	Low
M13	Female	Tibia	50-55	-6.9	8.3	--	44.8	15.8	--	3.3	--	--	W-E, Supine	None	Low
M43	Female	Tibia	25±	-7.1	9.9	--	41.6	13.8	--	3.5	--	--	W-E, Supine	None	Low
M55	Female	Rib	20±	-6.9	9.9	--	38.4	13.5	--	3.3	--	--	W-E, Supine	None	Low
M56	Female	Tibia	30±	-6.6	10.5	8.3	42.9	15.4	0.27	3.2	421	130	W-E, Supine	None	Low
M59	Female	Rib	40±	-7.1	8.8	--	42.0	14.6	--	3.4	--	--	W-E, Supine	None	Low
M68	Female	Humerus	25-30	-7.4	8.5	--	43.1	15.5	--	3.2	--	--	W-E, Supine	None	Low
M71	Female	Rib	30±	-6.7	9.7	7	44.0	15.8	0.28	3.2	420	130	W-E, Supine	None	Low
M77	Female	Tibia	20±	-7.1	9.7	7.9	42.7	15.2	0.32	3.3	358	110	W-E, Supine	None	Low
M82	Female	Rib	30-35	-7.2	9.0	--	41.2	14.8	--	3.2	--	--	W-E, Supine	None	Low
M83	Female	Tibia	30-35	-6.8	8.6	7.2	42.8	15.4	0.25	3.2	464	143	W-E, Supine	None	Low
M9	?	Humerus	Adolescent	-7.5	8.4	--	44.6	15.5	--	3.4	--	--	W-E, Supine	None	Low
M26	?	Rib	Adolescent	-6.9	9.8	--	44.7	15.8	--	3.3	--	--	W-E, Supine	None	Low

M37	?	Rib	Adolescent	-6.4	9.7	--	43.3	14.9	--	3.4	--	--	W-E, Supine	None	Low
M46	?	Rib	40±	-7.2	9.6	--	41.4	14.1	--	3.4	--	--	N-S, Supine	None	Low
M48	?	Tibia	Adolescent	-6.3	9.7	--	43.5	14.8	--	3.4	--	--	W-E, Supine	None	Low
M65	?	Rib	Adolescent	-6.6	9.3	--	43.5	15.6	--	3.3	--	--	W-E, Supine	None	Low
M70	?	Tibia	?	-14.9	10.1	8.8	44.9	16.5	0.19	3.2	622	196	N-S, Flexed	None	Low
M81	?	Tibia	?	-7.4	10.1	--	39.6	13.5	--	3.4	--	--	W-E, Supine	None	Low
M84	?	Humerus	?	-7.1	8.8	--	42.3	15.3	--	3.2	--	--	W-E, Supine	None	Low
M85	?	Tibia	?	-6.9	8.4	5.8	43.8	15.9	0.22	3.2	539	168	W-E, Supine	None	Low
M90	?	Tibia	?	-6.6	9.7	7.1	43.4	15.6	0.23	3.3	511	157	W-E, Supine	None	Low
M92	?	Rib	?	-7.4	9.3	--	43.7	15.8	--	3.2	--	--	W-E, Supine	None	Low
Samples below failed to produce collagen															
M8	Male	Rib	35±	--	--	--	--	--	--	--	--	--	W-E, Supine	None	Low
M11	?	Rib	12-13	--	--	--	--	--	--	--	--	--	W-E, Supine	Snail shell 贝 (<i>Cypraeidae</i>)	High
M16	?	Tibia	?	--	--	--	--	--	--	--	--	--	W-E, Supine	None	Low
M20	Male	Rib	25-30	--	--	--	--	--	--	--	--	--	W-E, Supine	None	Low
M31	Male	Rib	30-35	--	--	--	--	--	--	--	--	--	W-E, Supine	Pottery (Li 鬲)	Medium
M63	Male	Rib	25±	--	--	--	--	--	--	--	--	--	W-E, Supine	None	Low
M67	Female	Tibia	20±	--	--	--	--	--	--	--	--	--	W-E, Supine	None	Low
M79	?	Rib	?	--	--	--	--	--	--	--	--	--	W-E, Supine	Pottery (Li 鬲, Chalice 豆, Jar 罐)	Medium

Table 4.4S2. Isotopic results and sample information for the Proto-Shang fauna from the Nancheng and Baicun sites, Hebei Province, China

Sample	Site	Species	Bone	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	$\delta^{34}\text{S}$ (‰)	%C	%N	%S	C/N	C/S	N/S
H32	Baicun	Cattle	Femur	-8.1	8.3	8.6	43. 2	15. 6	0.2 2	3.2	517	186
H7	Baicun	Cattle	Femur	-10.9	8.2	9.0	43. 6	15. 8	0.2 2	3.2	532	192
H122: 3	Baicun	Cattle	Phalanx	-8.3	5.9	3.3	43. 1	15. 6	0.2 2	3.2	521	189
H23: 2	Baicun	Cattle	Tibia	-8.6	6.6	2.5	44. 3	16. 0	0.2 1	3.2	565	204
H28: 5	Baicun	Cattle	Mandible	-5.8	7.3	--	42. 9	15. 3	--	3.3	--	--
H42	Baicun	Sheep/Goat	Tibia	-16.4	8.1	--	41. 1	14. 8	--	3.2	--	--
H64	Baicun	Sheep/Goat	Tibia	-6.4	8.3	--	42. 3	15. 1	--	3.3	--	--
H52: 1	Baicun	Sheep/Goat	Tibia	-11.9	7.2	7.2	44. 6	16. 3	0.1 8	3.2	677	247
H23: 1	Baicun	Sheep/Goat	Tibia	-10.0	5.7	--	43. 6	15. 7	--	3.2	--	--

H28: 1	Baicun	Sheep/Goat	Radius	-13.1	7.0	--	43. 3	15. 8	--	3.2	--	--
H28: 2	Baicun	Sheep/Goat	Mandible	-11.2	5.3	--	43. 4	15. 6	--	3.3	--	--
H28: 3	Baicun	Sheep/Goat	Humerus	-12.2	6.0	--	42. 7	15. 3	--	3.2	--	--
H28: 4	Baicun	Sheep/Goat	Vertebrae	-11.5	5.1	--	43. 5	15. 7	--	3.2	--	--
H28:6	Baicun	Sheep/Goat	Scapula	-11.6	5.7	--	42. 9	15. 4	--	3.2	--	--
H67: 2	Baicun	Sheep/Goat	Mandible	-16.5	6.1	6.5	41. 8	15. 2	0.2 2	3.2	506	184
H122: 1	Baicun	Sheep/Goat	Tibia	-10.6	5.6	8.3	42. 8	15. 7	0.1 6	3.2	701	257
H2: 1	Baicun	Sheep/Goat	Metatarsu s	-13.4	5.8	--	43. 9	15. 9	--	3.2	--	--
H2: 2	Baicun	Sheep/Goat	Mandible	-12.8	5.3	--	42. 6	15. 2	--	3.3	--	--
H143: 1	Baicun	Deer	Radius	-20.4	3.3	--	40	14. 3	--	3.3	--	--
H143: 2	Baicun	Deer	Metatarsu s	-21.0	2.8	--	43. 5	15. 2	--	3.3	--	--

H143: 3	Baicun	Deer	Metatarsus	-21.3	3.2	--	42.8	14.8	--	3.4	--	--
H143: 4	Baicun	Deer	Humerus	-20.2	3.9	--	42.3	15.2	--	3.2	--	--
H62: 2	Baicun	Deer	Humerus	-21.1	3.9	12.8	43.8	15.9	0.24	3.2	481	174
H62: 1	Baicun	Sikka Deer	Scapula	-16.2	5.0	--	43.4	15.6	--	3.3	--	--
H22	Baicun	Dog	Radius	-6.9	7.6	6.8	44.3	16.1	0.18	3.2	643	233
H21	Baicun	Dog	Humerus	-9.1	6.9	8.2	45.2	16.2	0.22	3.3	537	192
H22	Baicun	Pig	Ulna	-7.2	7.4	--	43.2	15.4	--	3.3	--	--
H86	Baicun	Pig	Scapula	-6.5	8.3	7.9	43	15.3	0.2	3.3	567	202
H52: 2	Baicun	Pig	Humerus	-7.2	7.7	7.3	36.9	13.3	0.2	3.2	492	177
M25	Nancheng	Unidentified	--	-12.2	5.6	--	45	15.9	--	3.3	--	--
H57	Nancheng	Unidentified	--	-9.4	7.4	--	44.5	16.3	--	3.2	---	--

Samples below failed to produce collagen												
H122: 2	Baicun	Pig	Tibia									
H164: 1	Baicun	Pig	Pelvis									
H37: 1	Baicun	Pig	Mandible									
H37: 2	Baicun	Pig	Pelvis									
H67: 1	Baicun	Sheep/Goat	Tibia									

CHAPTER 5 Reconstructing Diet of the Early Qin (ca. 700 – 400 BC) at Xishan, Gansu Province, China

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Abstract

Here we report the bone collagen carbon and nitrogen isotopic results of humans (n=33) and animals (n=58) to reconstruct the dietary practices of an early Qin population dating to the Zhou Dynasty (Late Western-Early Eastern period ca. 700-400 BC) at the Xishan site in Gansu Province, China. The humans have a very large range of $\delta^{13}\text{C}$ (-23.3‰ to -7.1‰) and $\delta^{15}\text{N}$ (4.3‰ to 10.9‰) values which reflects extraordinarily diverse diets and included individuals with predominately C_3 as well as those with exclusive C_4 diets. This wide span of isotopic results produced a subtle linear trend ($R^2 = 0.62$) in the human data, which paralleled the animals across the C_3 and C_4 environmental gradient. However, the majority of the individuals had a predominately C_4 diet based on millet with $\delta^{15}\text{N}$ results only slightly elevated above the animals, except for the pigs and cattle. This is evidence that many of the animals were likely used for their secondary products, labor or as sacrificial offerings and that pork and beef were the main sources of animal protein for the population. High status individuals had elevated $\delta^{15}\text{N}$ values (10.2 ± 0.6 ‰) compared to medium (8.9 ± 0.3 ‰) and lower status (8.8 ± 0.8 ‰) individuals, possible related to increased animal protein in the diet. Differences related to gender were also found with females having elevated $\delta^{13}\text{C}$ (-11.2 ± 1.9 ‰) and $\delta^{15}\text{N}$ (9.4 ± 0.8 ‰) values compared to the males ($\delta^{13}\text{C} = -14.1 \pm 4.2$ ‰; $\delta^{15}\text{N} = 7.9 \pm 1.9$ ‰), but these results necessitate caution given the large number of individuals that could not be sexed. The results of this study support the view that the early Qin people were a more sedentary society focused on millet agriculture and animal husbandry, and that they were influenced by the pre-existing populations of the central Gansu region.

5.1 Introduction

Named after the first emperor of China (Qin, 221-206 BC), the Qin Dynasty is considered one of the most important and influential periods in all of Chinese history (Sima, 1962; Li, 1984). However, before the Qin people successfully unified China they were one of several feudal states “zhuhou guo” (诸侯国) vying for control of the region during the Zhou Dynasty (1046-221 BC) (Li, 1975). Since the Qin people are viewed as the direct ancestors which founded Imperial China, scholars have devoted large amounts of research to learning more about their early history, culture, and formation as a society to better understand how these people successfully rose to power (Duan, 1982; Ma, 1982; Xu, 2003).

The Qin people are believed to have originated in East China as the “Yi” (夷) people around 1000 BC. At some point during the early Zhou Dynasties (ca. 890 BC), one group of Qin moved to the western part of China (what is now eastern Gansu Province) and lived among the nomadic “Rong” (戎) groups (Zou, 1980; Duan, 1982; Liu, 2003). Recent archaeological excavations have confirmed this, and identified Li County in eastern Gansu Province as the earliest place where the Qin settled in this region (Liang et al., 2008) (Figures 5.1a,b). These excavations yielded many important cemeteries (e.g. Dabaozi and Yuandingshang) and architectural remains which have been used to identify unique customs and aspects of the Qin culture, dating from the late phase of the Shang Dynasty (1400-1046 BC) through the Zhou Dynasty (1046-256 BC) (Liang et al., 2008).

Previous studies that examined the subsistence strategy of early Qin populations have produced conflicting results, and this topic remains an active area of debate (Zhang, 2001; Wang, 2007). Many historians believed that the early Qin population adopted a nomadic pastoral lifestyle and diet when they migrated to eastern Gansu, since ancient texts, such as *Shiji* (Sima, 1962), describe many activities relating to animal herding and hunting for the early Qin. In contrast, some archaeologists hold the view that the early Qin population adopted a more sedentary lifestyle based on farming, as indicated by the archaeological evidence from pottery vessels used for storing grains and tools related to farming. A single limited study of isotopic results and dental health patterns determined that people in Xishan had a diet that was a mix of stockbreeding and agriculture (Wei,

2008; Wei et al., 2009). Unfortunately, no faunal isotope results were measured so it was impossible to determine the types of animals or plant protein that was consumed by the people of Xishan. In addition, there have been only two previously published isotopic studies of Qin sites (both did not contain faunal results) and these were from Shaanxi Province to the east and were from later time periods (Ling et al., 2010a; 2010b). While historical sources and archaeological evidence indicate that the early Qin period consisted of different cultural groups with a complex social structure and order, previous research was not able to explore if there were possible differences related to status. Here we present a detailed application of stable isotope ratio analysis of human (n=33) and faunal remains (n=58) from the Xishan site. We selected available human skeletal remains from different contexts as well as faunal samples to establish the isotopic baseline with which to compare to the humans. We aimed to reconstruct the picture of daily life of the early Qin population in this region and to examine if social status and gender were possibly reflected in the different diets of the individuals.

5.1.1 Stable isotope ratio analysis and palaeodiet

Carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) stable isotope ratio analysis of bone collagen is a well-established method used to reconstruct the diet of modern past populations and has been widely applied to address questions of subsistence practices, animal husbandry strategies, health and nutrition, and social status (e.g. van der Merwe and Vogel, 1978; Sealy et al., 1987; Richards et al., 1998; Fuller et al., 2004; Müldner and Richards, 2007; Hu et al., 2009; Choy et al., 2010; Bourbou et al., 2011; Commendador et al., 2013; Cui et al. 2015). Based on the principle that the various body tissues are derived from dietary intake, isotope ratios obtained from bone collagen reflect the average isotopic composition of an individual's dietary protein intake over the entire lifetime including a significant amount of collagen from the period of adolescences (Stenhouse and Baxter, 1979; Hedges et al., 2007).

The $\delta^{13}\text{C}$ results can distinguish between diets composed primarily of C_3 (plants adapted to temperate ecosystems, including most vegetables, fruit and wheat) and C_4 (plants adapted to hot and arid ecosystems, including maize, millet and some grasses) photosynthetic pathway plants, as well as the animals that consumed these (DeNiro and Epstein, 1978; Krueger and Sullivan, 1984;

Schwarcz, 1991; Ambrose and Norr, 1993; Kellner and Schoeninger, 2007). The $\delta^{15}\text{N}$ results can be used to examine the trophic level, since body tissues show an approximately 3–5‰ enrichment in $\delta^{15}\text{N}$ relative to diet (DeNiro and Epstein, 1981; Minagawa and Wada, 1984; Schoeninger and DeNiro, 1984; Bocherens and Drucker, 2003; Hedges and Reynard, 2007). Isotopic ratios can also detect the contribution of marine protein in the diet, since both the carbon and nitrogen isotope values vary between marine and terrestrial ecosystems in a predictable manner (Chisholm et al., 1982; Schoeninger et al., 1983; Richards and Hedges, 1999). However, a comprehensive discussion about how stable isotope ratios can be used to reconstruct dietary patterns in archaeological populations is beyond the scope of this study, and the reader is directed to the following excellent reviews for more information (Schwarcz and Schoeninger, 1991; Schoeninger, 1995; Katzenberg, 2000; Lee-Thorp, 2008; Reitsema, 2013).

5.1.2 The Xishan site, Gansu Province, China

The Xishan site is one of the most important archaeological sites in eastern Gansu Province, and is located on a hillside in the eastern portion of Li County. Excavations have yielded a cemetery, ritual sacrifice pits, and ruins of a fortified wall, indicating it was a central settlement for the early Qin population during the late Western Zhou (1046-771 BC) to the Eastern Zhou periods (770-221 BC). In particular, 49 graves with various burial contexts were recovered, providing materials to better understanding the daily life in the early Qin period and Qin society in general. Six of the tombs were dated to the Late Western Zhou period, and were clearly separated into two clusters according to location and burial custom. Three tombs were oriented W-E and located on the top of the hill with the interred lying face up with arms crossed over the body, accompanied with rich grave goods, and as well as sacrificial victims and dogs. For example, individual M2003 was buried in a decorated wooden coffin that contained plentiful artifacts, including jade, bronze ritual objects (3 tripod and 2 Gui “簋” style vessels; Gui is a bowl-shaped ancient Chinese ritual bronze vessel used to hold food offerings) likely related to the upper *Shi* (士) orders indicating it was a very high status grave (see Figure 5.1c). The other three tombs, oriented N-S, were located to the south of the hillside with very few grave goods. The remaining 43 tombs dated to the Eastern Zhou period, and these burials were positioned in the W-E direction. Most of the individuals from those tombs were buried with a flexed posture and the accompanying grave goods included: pottery

vessels, bronze weapons, jade, with variations in number and quality for each tomb.

5.2 Materials and Methods

Fifty-eight faunal bone samples found either in a ritual sacrifice pit, the fill of the cemetery during excavation, or inside of a tomb were collected and available for analysis (Table 5.1). The identification of faunal species was conducted by the Institute of Archaeology, CASS (Yu et al., 2011), and represented eight species, including sheep, horse, deer and dog, which makes it possible to reconstruct the past food web, and provides the necessary baseline for understanding the human isotope values. In addition, thirty-three human skeletal remains were available for analysis, and prior to isotope analysis, age estimation and sex determination for each individual (where possible) were undertaken by one of the authors (L. Chen). However, a number of the tombs were looted in the past, and the bones of these individuals were scattered, disarticulated, and commingled and identification was not possible (Table 5.2), but as only ribs or long bones were sampled it is believed that all specimen represent separate individuals.

Bone collagen was extracted by the protocol described in Richards and Hedges (1999) with the addition of an ultrafiltration step as recommended by Brown et al. (1988) and Jørkov et al. (2007). Each bone sample was cleaned by air abrasion and then put into 0.5 M HCl solution at 4 °C for ~2 weeks, with acid changes every 2 days. Demineralized samples were gelatinized at 70 °C in a pH=3 solution for 48 hours. After purification with a 5µm EZEE[®] filter, the solution was concentrated by Amicon[®] ultrafilters (<30 kDa), and then was frozen and freeze dried for 2 days. Approximately 0.5 mg of extracted collagen was weighted for carbon and nitrogen analysis, using a Flash EA 2112 coupled to a Delta XP mass spectrometer (Thermo-Finnigan, Bremen, Germany). The results are reported in 'per mil' (‰) relative to the standards VPDB for $\delta^{13}\text{C}$ and AIR for $\delta^{15}\text{N}$. The analytical precision is $\pm 0.2\text{‰}$ for both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$.

5.3 Results and Discussion

The mean $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results were calculated using duplicate measurements of each sample,

and the C:N, %C, %N values were also measured (Tables 5.1, 5.2). All of the humans (33 out of 33) and 52 out of 58 of the faunal samples produced collagen that met the published quality criteria for well-preserved collagen (DeNiro, 1985; van Klinken, 1999).

5.3.1 Faunal isotope data

The fauna samples exhibit a wide range of $\delta^{13}\text{C}$ (~16‰) and $\delta^{15}\text{N}$ (~9‰) results that spanned a complete C_3 to C_4 dietary range (Figure 5.2). The majority of the animals date from the Zhou Dynasty (Late Western-Early Eastern period ca. 700-400 BC), but six animals are believed to date earlier, from the late Neolithic, based on the levels at which they were discovered. However, no noticeable isotopic differences are observed between these six specimens and the other samples (Table 5.1) so all will be treated as reflecting the likely isotopic baseline of the humans during the Zhou Dynasty.

The herbivores (horse, deer, sheep, goat, cattle, bear; n=30) omnivores (dog, pig; n=18) and unidentified faunal (n=4) $\delta^{13}\text{C}$ values range from -23.1‰ to -7.3‰ and the $\delta^{15}\text{N}$ values range from 2.0‰ to 10.9‰. The horses (n=3) have a mean \pm sd $\delta^{13}\text{C}$ value of 18.7 ± 0.7 ‰ and mean \pm sd $\delta^{15}\text{N}$ value of 6.9 ± 0.4 ‰. The sheep (n=5) have a mean \pm sd $\delta^{13}\text{C}$ value of -18.4 ± 0.7 ‰ and mean \pm sd $\delta^{15}\text{N}$ of 6.7 ± 1.7 ‰, while the goats (n=5) have mean \pm sd $\delta^{13}\text{C}$ value of -18.8 ± 0.6 ‰ and a mean \pm sd $\delta^{15}\text{N}$ value of 6.5 ± 1.1 ‰. These results indicate these three species fed on similar diets that were predominately based on C_3 plants (Figure 5.2). One of the sheep has an elevated $\delta^{15}\text{N}$ signature which might reflect nursing as it was identified as a juvenile between 6-28 months old (Balasse and Tresset, 2002).

The deer (n=9) have mean \pm sd $\delta^{13}\text{C}$ (-20.5 ± 1.7 ‰) and $\delta^{15}\text{N}$ (5.1 ± 1.4 ‰) values reflecting a nearly exclusive C_3 diet. However, a single individual (M2004) plots away from the group and shows a significant ^{13}C -enrichment, indicating it was having substantial amounts of C_4 foods (likely millet) in its diet (Table 5.1; Figure 5.2). This could reflect that this deer was kept as a pet or sacrificial animal and fed by humans at the site. The cattle (n=7) have mean \pm sd $\delta^{13}\text{C}$ (-17.3 ± 4.4 ‰) and $\delta^{15}\text{N}$ (5.4 ± 1.3 ‰) values and display a wide range of $\delta^{13}\text{C}$ (-23.1 ‰ to -12.0 ‰) and $\delta^{15}\text{N}$ (3.7 ‰ to

6.6‰) values, indicating they consumed a much more diverse range of foods at Xishan. Two of the cattle have isotopic results close to the horse and sheep/goat assemblage indicating similar animal husbandry strategies were used with this cluster of animals (Figure 5.2). In addition, two cattle have the most ^{13}C -depleted results of all the species studied, and these individuals had exclusive C_3 diets that could reflect that they were wild and grazing in a closed forested habitat due to the canopy effect (France, 1996; Vera, 2000; Drucker et al., 2008). The final three individuals have ^{13}C -enriched values that plot below the dogs and reflect that these cattle were likely cared for in or near the settlement and foddered with significant amounts of millet. The isotopic results of the single bear reflect that it was having a herbivorous C_3 diet and a similar pattern has been observed in Europe (Bocherens et al., 1994; Bocherens et al., 1997).

The mean \pm sd $\delta^{13}\text{C}$ ($-13.3\pm 3.9\%$) and $\delta^{15}\text{N}$ ($6.8\pm 1.3\%$) values of all the pigs ($n=9$) cluster in two groups (Figure 5.2). However, three pigs have mean \pm sd $\delta^{13}\text{C}$ ($-18.0\pm 0.6\%$) and $\delta^{15}\text{N}$ ($5.1\pm 0.1\%$) values that are near some of the cattle, horses and sheep/goats, suggesting that these animals were all cared for and fed in a similar manner. It is also possible that these C_3 pigs might be wild boar as suggested by past research (Pechenkina et al., 2005; Barton et al., 2009). The rest of the pigs have $\delta^{13}\text{C}$ values that range between -14.5% to -8.7% (mean \pm sd; $-10.9\pm 2.1\%$) and $\delta^{15}\text{N}$ values that range between 6.5% to 8.1% (mean \pm sd; $7.6\pm 0.6\%$). These pigs were eating a predominately C_4 diet (millet), and the elevated $\delta^{15}\text{N}$ values suggest that they were fed scraps or refuse by the humans and thus domesticated. The dogs ($n=9$) have some of the most ^{13}C -enriched (mean \pm sd; $-11.4\pm 2.2\%$) and ^{15}N -enriched (mean \pm sd; $6.8\pm 1.3\%$) values of all the animals, suggesting a significant and regular consumption of C_4 protein in their diet, which is a common pattern observed in isotopic studies of domesticated dogs in north China (Chen et al., 2012; Hou et al., 2013; Si, 2013).

5.3.2 Human isotope data

The isotopic results and information for the humans measured in this study are presented in Table 5.2 and plotted in Figures 5.3a and 5.3b. In addition, eight human $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from the work of Wei (2008) are also listed in Table 5.2 and shown in Figures 5.3a and 5.3b so that there are a total of 41 humans that can be isotopically examined and discussed from the Xishan site.

Like the animals, the humans show a wide range of $\delta^{13}\text{C}$ (-23.3‰ to -7.1‰) and $\delta^{15}\text{N}$ (4.3‰ to 10.9‰) results. This reflects that the diet of the early Qin at Xishan was extraordinarily diverse and included individuals with a nearly complete C_3 diet as well as those with an exclusive C_4 diet. In addition, a subtle but clear linear trend ($R^2= 0.62$) is observed for the humans which parallels the faunal results. However, in many cases the humans plot with or only slight above the animals (an exception being the C_4 pigs and cattle) indicating the animals were not regularly consumed, but likely used for their labor or secondary products (Figures 5.3a,b), and this is observed at other sites in China (e.g. Li et al., 2014).

5.3.3 The subsistence patterns of the early Qin population

The data presented here indicate that the early Qin population at Xishan had a diverse diet that spanned a range of complete C_3 to C_4 resources. However, the majority of the population (35 out of 41 individuals) were eating a predominately C_4 ($> -12\text{‰}$) or mixed C_3/C_4 diet ($> -18.0\text{‰}$) (Pechenkina et al., 2005; Barton et al., 2009). This is clear evidence that millet farming was highly important to the Qin people. Flotation, studies confirm the presence of carbonized millet grains, and broomcorn millet (*Panicum milaceum*) is considered to have been the main C_4 plant in this region (Wang, 2006; Chen, 2007; Li et al., 2007; Zhou et al., 2011). Thus, millet was an integral part of the diet, culture, and history either through direct consumption and/or by the consumption of animals fed on millet. Given that millet grows quickly and requires little human assistance to produce a yield, it is an ideal crop for a possible nomadic/pastoral population such as the Qin (Chen, 2007). However, the isotopic results indicating, that large quantities of millet were consumed by the inhabitants coupled with the low trophic level of the humans compared to the animals (see below), is compelling evidence that the Qin were a settled agriculture population at the Xishan site.

However, the human $\delta^{15}\text{N}$ results are nearly identical or only slightly elevated above the fauna (Figures 5.3a,b), and this provides strong support that most of these domestic animals were not readily consumed but also used for their secondary products, labor, or sacrificial importance. Exceptions to this include the pigs and cattle, as many of the individual humans are clearly elevated in $\delta^{15}\text{N}$ by comparison (Figure 5.3a), and this agrees with the historical accounts. In particular,

written records mentioned six kinds of animals such as pig, dog, cattle, sheep/goat, horse and chicken as being very important domestic breeds in the pre-Qin period (Yang, 2008; Flad et al., 2009; Yuan, 2012). They were widely used for protein food sources (e.g. pig), sacrificial or ritual killing (e.g. dog, pig and horse), vehicle and farming labor (e.g. horse and cattle), and also for military purposes (horse). An abundance of pits which contained slaughtered animals were found at the Xishan site, including seven horse pits, one cattle pit, and three pits with dog and other assorted fauna pits, indicating the wide range of domesticated animals that were available in the early Qin period. Only two other isotopic studies have been published on Qin sites (Sunjianantou and Jianhe), and both of these were from the neighboring Province of Shaanxi and date to later periods (Ling et al., 2010a; 2010b). When the results presented here from Xishan are compared to the Sunjianantou and Jianhe sites, we see similar patterns (Figure 5.4) with individuals at all three sites having a heavy reliance on millet and similar $\delta^{15}\text{N}$ values. However, there is clearly more dietary diversity at Xishan. It is difficult to make more detailed comparisons as no faunal remains were analyzed at the Sunjianantou and Jianhe sites, but it is possible that the sources of animal protein were similar at the three sites and more isotopic work on both humans and animals is necessary from additional Qin sites. To summarize, we infer from the results of this study that the early Qin population brought a millet agriculture system with them when they immigrated to Xishan, and simultaneously adopted and exploited a stockbreeding and animal husbandry regime that was influenced by the pre-existing populations of the central Gansu region. This discovery supports the archaeologist's view that the early Qin people were a more sedentary and agriculture-based society at the Xishan site.

5.3.4 Dietary variation relating to social status

Both textual and archaeological evidence imply that the early Qin society was characterized by considerable social complexity with a range of status differences (Ge, 1992; Dai, 2006). If we assume that the upper class individuals had more access to wealth, power and the means of production, they may have set themselves apart from the majority by consuming foods that were perhaps more nutritious, exotic or rarer to obtain. The most direct evidence to determine wealth and status differences among individuals is from the mortuary analysis (Table 5.2). Unfortunately, only 16 individuals could be assigned a clear status level (low, medium, high) as the others had

tombs that were partially or completely looted in the past. However, examination of these isotopic results shows that while all classes had similar $\delta^{13}\text{C}$ values, the $\delta^{15}\text{N}$ results of the high status ($10.2\pm 0.6\text{‰}$) individuals were significantly elevated over the medium ($8.9\pm 0.3\text{‰}$) and lower status ($8.8\pm 0.8\text{‰}$) individuals (one way ANOVA test; $p=0.039$; Figure 5.5). This could indicate that high status individuals were having more pork (or other high nitrogen isotope protein sources) in their diet compared to the common people, but this is only a preliminary conclusion as the number of samples in this population with known status is small.

5.3.5 Tomb owners vs. sacrificial victims

Four cases of human sacrifice were found at Xishan (Chen, 1989; Liang et al. 2008), and this confirms the presence of pronounced social differences within the population. It is unknown how these individuals were killed as no obvious signs of trauma were observed, but historical sources indicate that the Qin would sometimes poison, hang, or bury individuals alive that were to be sacrificed, and that most were unwilling participants, but that some viewed it as an honor to be buried with their master (Wen and De, 1998; Gan, 2008). For burial M2003, only the two sacrificed victims (M2003 1* and M2003 2*) could be analyzed as the skeleton of the tomb owner was missing. The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of M2003 1* and M2003 2* are nearly identical and indicate that both had similar diets even though the status of M2003 2* is inferred to be high based on the number and value of the associated grave goods (Table 5.2). In contrast, the two sacrificial victims (M1027 1* and M1027 2*) of burial M1027 have different $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values even though both are considered low class (Figure 5.3a, Table 5.2). The tomb owner (M1027; $\delta^{13}\text{C} = -9.1\text{‰}$, $\delta^{15}\text{N} = 10.0\text{‰}$) has similar isotopic result to one of the sacrificed individuals (M1027 1*; $\delta^{13}\text{C} = -8.9\text{‰}$, $\delta^{15}\text{N} = 9.6\text{‰}$) with both of these individuals consuming a predominately C_4 diet which included pork (Table 5.2). However, M1027 2* has significantly lower $\delta^{13}\text{C}$ (-13.7‰) and $\delta^{15}\text{N}$ (7.3‰) values indicating a significantly different diet that was based more on a mixture of C_3/C_4 foods, possibly including beef (Figure 5.3a, Table 5.2).

There is the intriguing possibility that the isotope data can further illuminate the identity of these sacrificial victims. Written records indicate that the life and diet of the sacrificed was determined by their owner (Chen, 1989; Wen and De, 1998; Gan, 2008). Those individuals that had a similar

dietary preference with their tomb master may not have necessarily had an inferior life history, and on the contrary could reflect individuals who had a close relationship with their master, such as concubines, retainers and liegeman (Ling et al., 2010a). In contrast, different dietary patterns compared to a tomb owner may suggest a more distant or subordinate relationship with their master, possibly a slave. This could have been the case for tomb M1027 where the tomb owner (an older female) might have had a close everyday relationship with the first sacrificed individual (M1027 1* - younger female; possible servant girl), but the second sacrificed individual (M1027 2* - unsexed young individual) was treated more as a slave for menial or undesirable work (Figure 5.3a, Table 5.2). Unfortunately, there is a scarcity of complete data for the other tombs, and the current sample size is too small to draw any larger conclusions from these comparisons. Further studies of the early Qin from other more undisturbed sites will help us to understand the dietary differences related to social status between the main tomb occupants and the sacrificial victims buried with them.

5.3.6 Isotopic differences associated with sex

Historical writings indicate that the Qin were a male dominated society (e.g. Duan, 2005; Zhao, 2008). However, there is evidence that the Qin were somewhat more progressive and that females enjoyed some additional freedoms and rights compared to other contemporary states such as the Chu (Gu, 2003). For example, records indicate that it was common in some cases for a man to marry a woman and live with the family of his wife when she had more wealth, and in these instances, the woman was the most powerful individual of the household (Zu, 2012). In addition, historical sources mention that the Qin state had a group of female soldiers that made up part of the army (Dong, 1956; Liu, 1998). However, there is no information concerning possible dietary differences that existed between the sexes during the Qin period. Here we examine the isotopic results of the identified males (n=9) and females (n=12) at Xishan to examine if different diets were consumed. The mean \pm sd $\delta^{13}\text{C}$ values of the males ($-14.1 \pm 4.2\text{‰}$) and females ($-11.2 \pm 1.9\text{‰}$) were found to be significantly different ($p = 0.047$) using a one way ANOVA test (Figure 5.6). This indicates that the males consumed a mixed C_3/C_4 diet and that the females had a more C_4 -based diet. In addition, the mean \pm sd $\delta^{15}\text{N}$ values of the males ($7.9 \pm 1.9\text{‰}$) and females ($9.4 \pm 0.8\text{‰}$) were also determined to be significantly different ($p = 0.024$) using a one way ANOVA test (Figure

5.6). It is particularly interesting that the males have lower $\delta^{15}\text{N}$ values compared to the females as past isotopic research usually finds the opposite results (e.g. Fuller et al., 2006; Richards et al., 2006; Quintelier et al., 2014). These findings at Xishan suggest that the females were consuming a diet of more millet and pork while the males had a much more diverse diet that was a mix of millet/rice/wheat and different animals both wild and domestic (Li et al., 2007). The reasons for these differences are unclear and could suggest that males had greater access to dietary items through hunting or travel related to trade or warfare while the females had a more homogenous diet related to foodstuffs found in and around the settlement. However, the number of individuals that could be reliably sexed is small at Xishan, and it is possible that if the large number unidentified individuals ($n=20$) could have had their sex determined that these isotopic differences would disappear. Thus, we highlight the need for caution with these interpretations and recognize that additional isotopic studies from Qin populations are needed in the future.

5.4 Conclusion

This study represents the largest and most detailed assessment of stable isotope ratio results from an early Qin population in China, the site of Xishan. The results found that millet was an important food resource in the diets of most of the humans and their livestock, but that the population had a very diverse diet that spanned nearly complete C_3 to C_4 diets for some individuals. A subtle linear trend ($R^2 = 0.62$) is observed for the humans, which parallels the trend for the fauna. However, in many cases the humans plot with or only slightly above the animals (an exception being the C_4 pigs and cattle) indicating that they were not regularly consumed, but likely used for their labor, secondary products or sacrificial importance. Examination of the human isotopic results by status found that high status individuals had significantly elevated $\delta^{15}\text{N}$ results compared to the low or middle status individuals, possibly reflecting increased pork consumption. However, the small sample size means that caution is warranted for these interpretations, and more work is needed from other non-looted early Qin sites. Significant differences related to gender were also found with females having elevated $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values compared to the males, but we strongly recommend caution in the interpretation of these results as a large number of individuals could not be sexed. We suggest that while the early Qin undertook a mixed subsistence strategy, they were

mainly focused on millet agriculture and stockbreeding, and that the population was settled rather than a nomadic or pastoral based society; supporting the views of the archaeologists that excavated Xishan. This study adds to the growing body of isotope data from China and shows the importance of both millet agriculture and animal husbandry in the formation of early Chinese state society.

5.5 Acknowledgement

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5.7 Figures

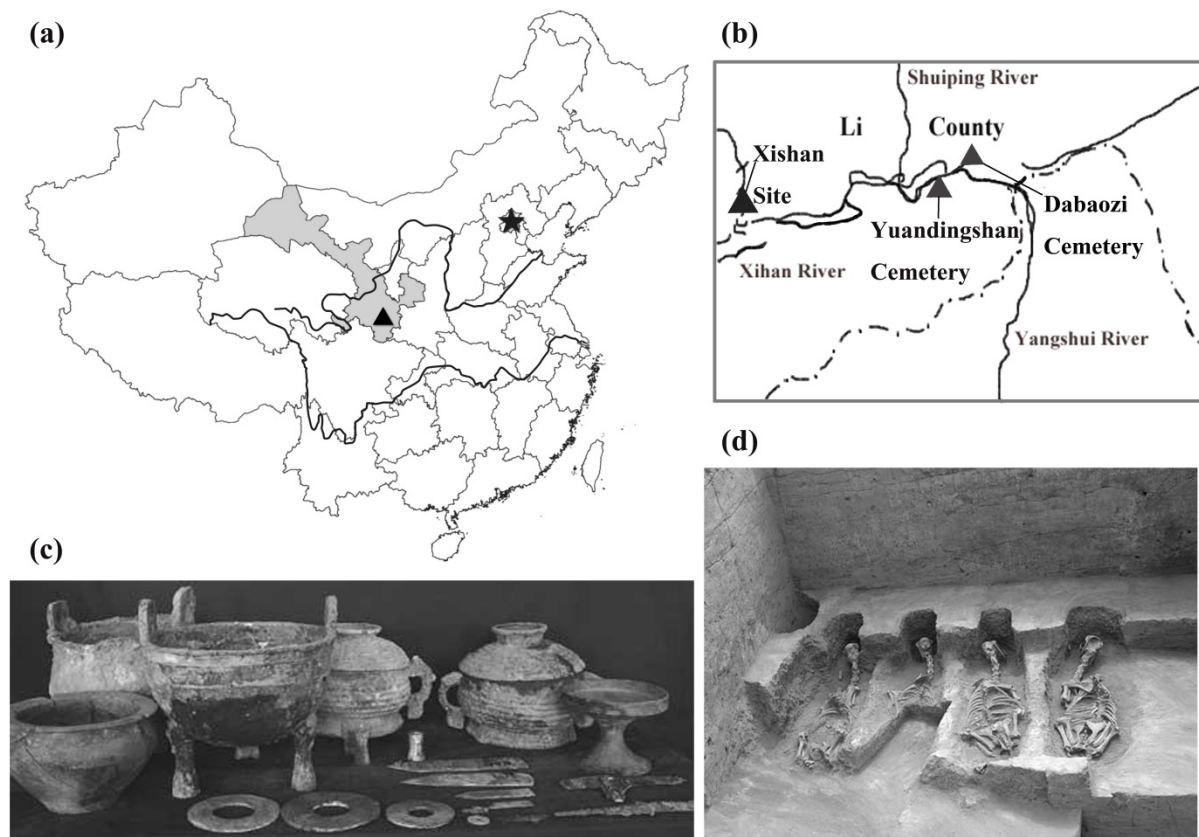


Figure 5.1. a) Map of China showing the location of the Xishan site (▲) in Gansu Province (shaded). Note (★) represents Beijing b) Expanded map showing the location of the Xishan site in Li County. c) Picture of the grave goods recovered from burial M2003. d) Picture showing the sacrificial horse pit K404.

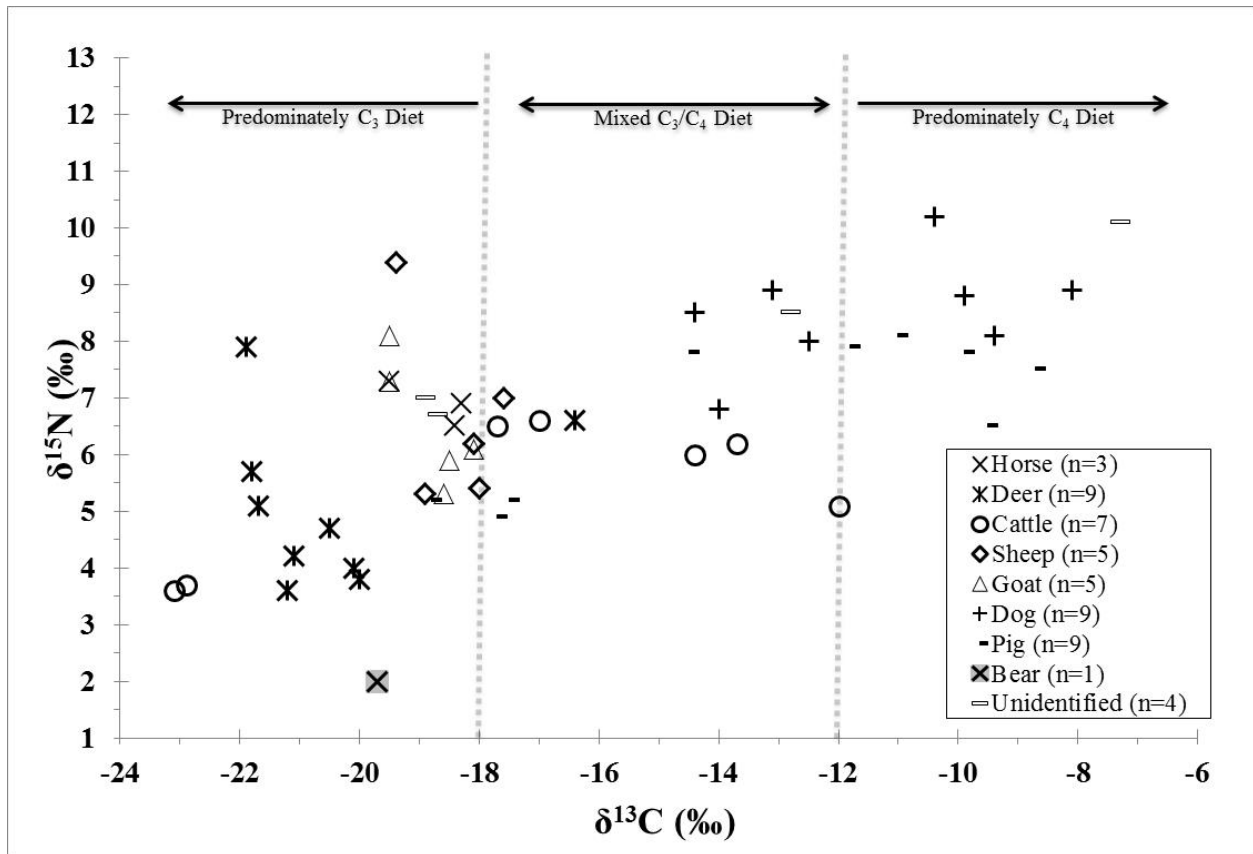


Figure 5.2. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ faunal results from the Xishan site Gansu Province, China. It is estimated that values $> -12\text{‰}$ reflect a predominately C₄ diet, values between -12‰ to -18‰ indicate a mixed C₃/C₄ diet, and values < -18 reflect a predominately C₃ diet in China according to the work of Pechenkina et al. (2005) and Barton et al. (2009).

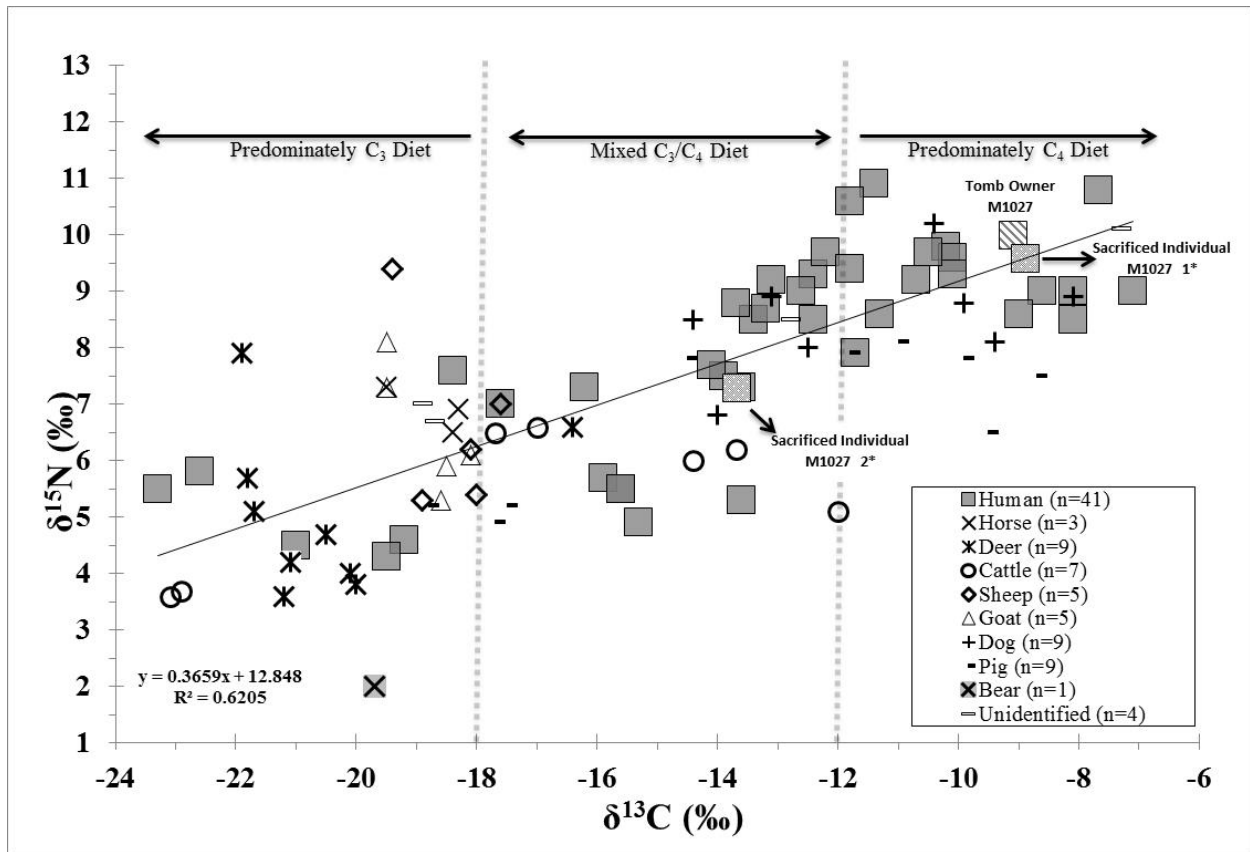


Figure 5.3a. Human and faunal $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from the Xishan site Gansu Province, China. Highlighted are the three individuals found in tomb M1027, consisting of the tomb owner (M1027) and two sacrificed individuals (M1027 1* and M1027 2*). It is estimated that values $> -12\text{‰}$ reflect a predominately C_4 diet, values between -12‰ to -18‰ indicate a mixed C_3/C_4 diet, and values < -18 reflect a predominately C_3 diet in China according to the work of Pechenkina et al. (2005) and Barton et al. (2009).

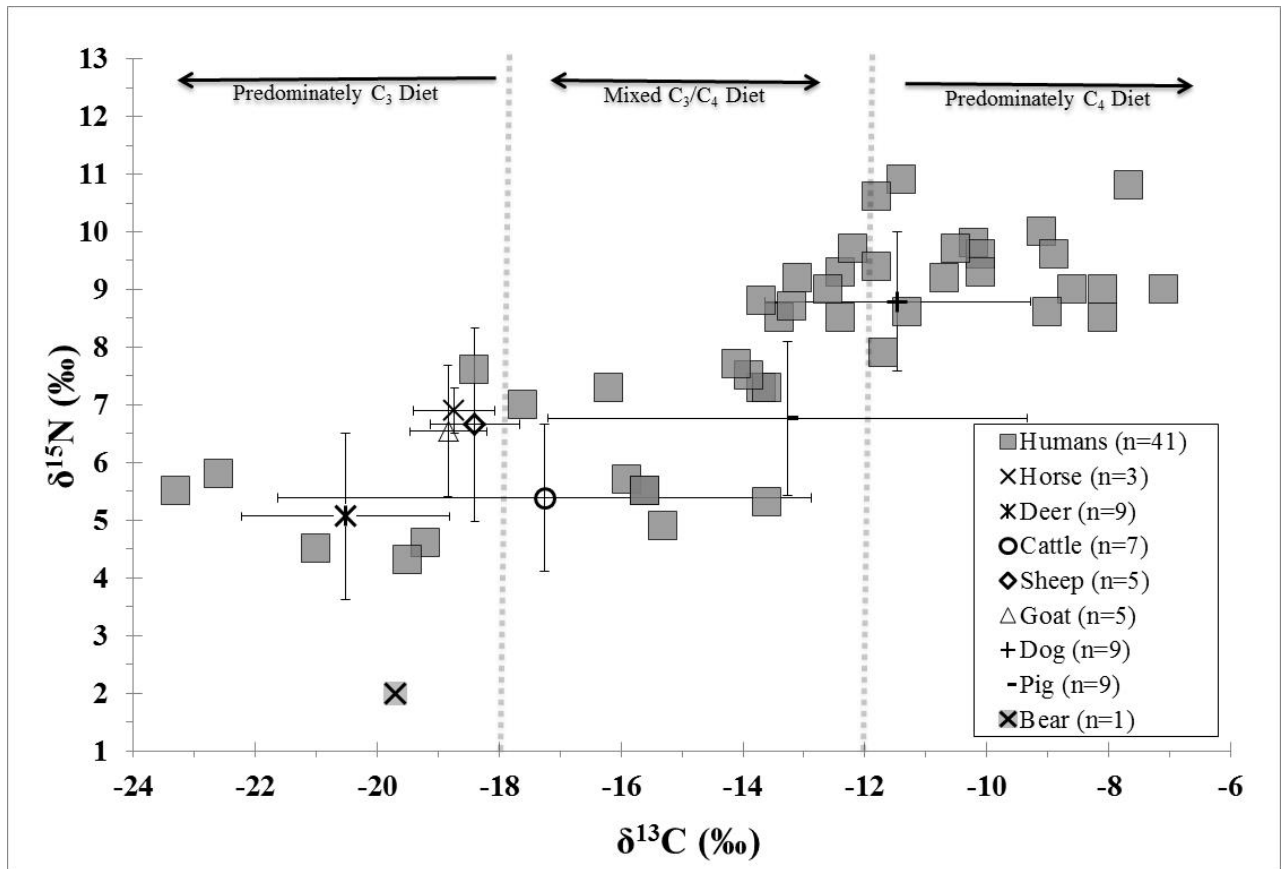


Figure 5.3b. Human and faunal mean \pm sd $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from the Xishan site Gansu Province, China. It is estimated that values $> -12\text{‰}$ reflect a predominately C₄ diet, values between -12‰ to -18‰ indicate a mixed C₃/C₄ diet, and values < -18 reflect a predominately C₃ diet in China according to the work of Pechenkina et al. (2005) and Barton et al. (2009).

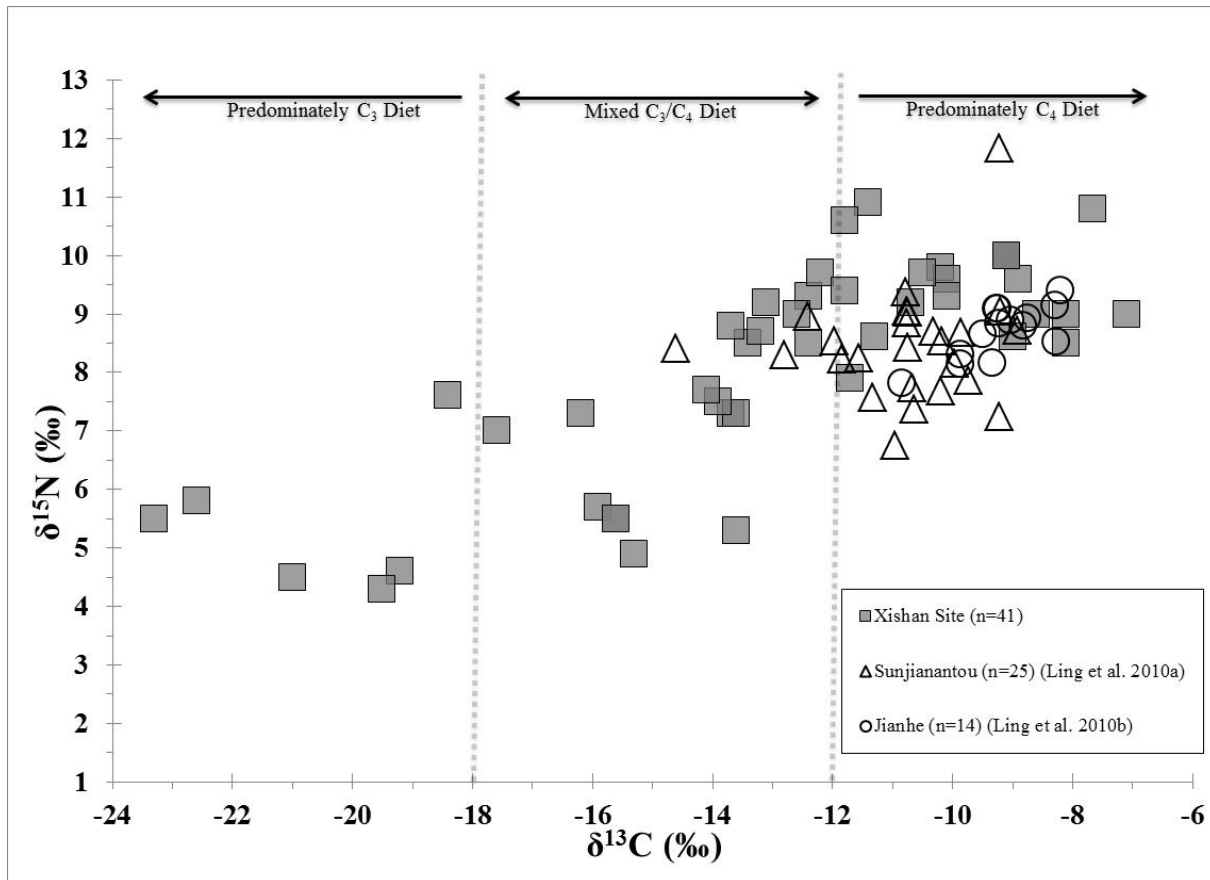


Figure 5.4. Comparison of the human $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from the Qin sites of Xishan, Sunjianantou (Ling et al., 2010a) and Jianhe (Ling et al. 2010b). All three sites show that individuals were consuming large amounts of millet but that Xishan had the largest dietary diversity. It is estimated that values > -12 ‰ reflect a predominately C₄ diet, values between -12 ‰ to -18 ‰ indicate a mixed C₃/C₄ diet, and values < -18 reflect a predominately C₃ diet in China according to the work of Pechenkina et al. (2005) and Barton et al. (2009)

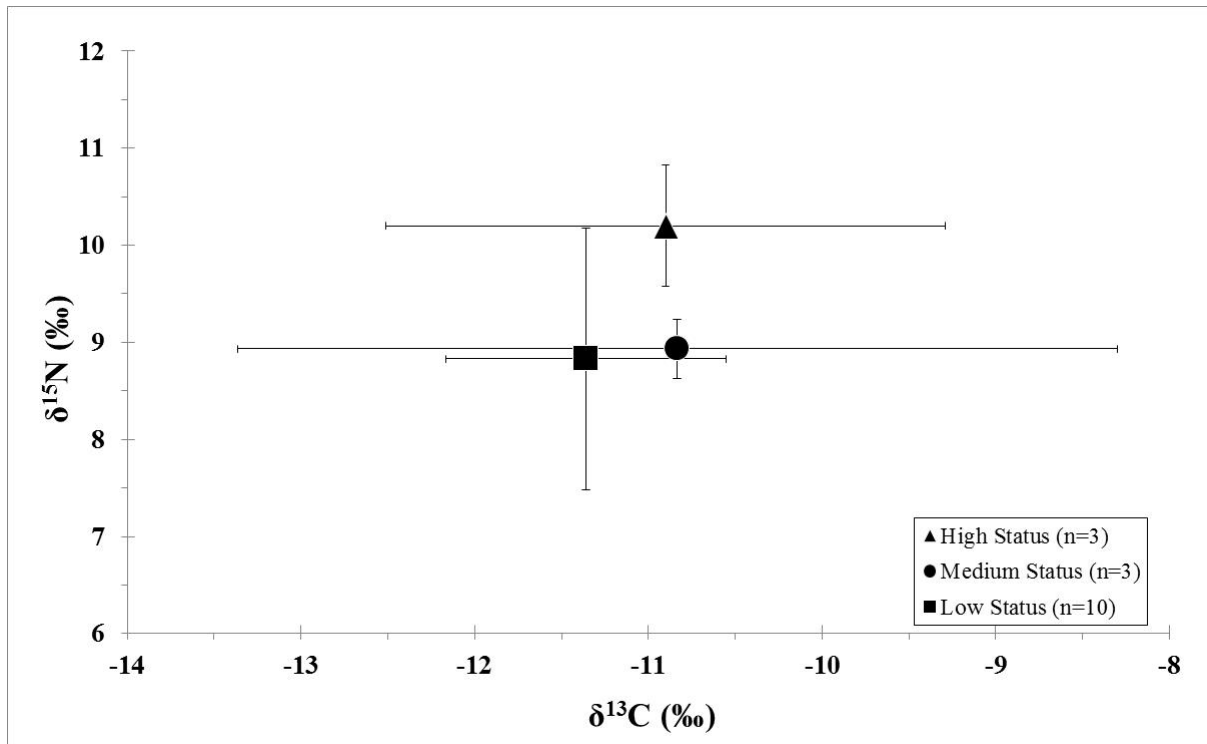


Figure 5.5. The mean \pm sd $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results for individuals that could be assigned status based on associated grave goods recovered from tombs at the Xishan site Gansu Province, China. High status individuals had $\delta^{15}\text{N}$ values that were significantly different ($10.2 \pm 0.6\text{‰}$) than medium ($8.9 \pm 0.3\text{‰}$) and low status ($8.8 \pm 0.8\text{‰}$) individuals (one way ANOVA test; $p=0.039$).

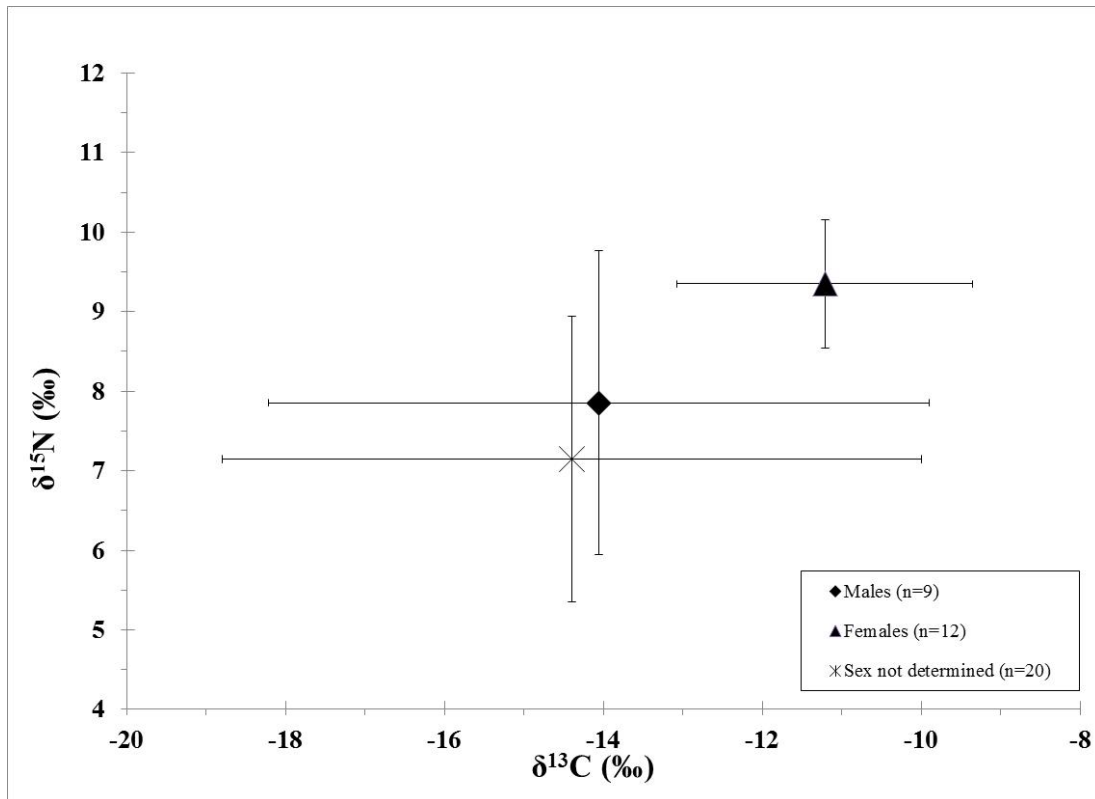


Figure 5.6. The mean \pm sd $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results for males, females, and sex not determined at the Xishan site Gansu Province, China. Significant differences were found for the $\delta^{13}\text{C}$ ($p = 0.047$) and $\delta^{15}\text{N}$ values ($p = 0.024$) between the males and females using a one way ANOVA test, but caution is suggested for these results given the high number of individuals where the sex was not determined.

5.8 Supplementary Tables

Table 5.1. Isotopic results and sample information for all fauna from the Xishan site, Gansu Province, China.

ID #	Species	Period	Burial Location	% Yield	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	%C	%N	C/N
M1007	Horse	Zhou Dynasty (Late Western-Early Eastern)	Tomb	0.1	-19.5	7.3	45	15.7	3.3
K102	Horse	Zhou Dynasty (Late Western-Early Eastern)	Sacrifice Pit	0.6	-18.4	6.5	44	15.5	3.3
K102	Horse	Zhou Dynasty (Late Western-Early Eastern)	Sacrifice Pit	1.5	-18.3	6.9	44.4	15.8	3.3
H1053	Deer	Late Neolithic	Fill	2.1	-21.7	5.1	44.4	15.9	3.3
T0205(5)	Deer	Late Neolithic	Fill	3.2	-21.9	7.9	45.8	16.1	3.3
H1063(2)	Deer	Zhou Dynasty (Late Western-Early Eastern)	Fill	2.7	-21.1	4.2	45.2	16.1	3.3
T0105(2)	Deer	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.6	-21.2	3.6	44.7	15.7	3.3
T0102(3)	Deer	Zhou Dynasty (Late Western-Early Eastern)	Fill	0.7	-20	3.8	44.6	15.8	3.3
M2004	Deer	Zhou Dynasty (Late Western-Early Eastern)	Tomb	1.2	-16.4	6.6	44.6	15.8	3.3
H1063(2)	Deer	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.9	-20.5	4.7	44.4	15.9	3.3
H1137	Deer	Zhou Dynasty (Late Western-Early Eastern)	Fill	1.8	-21.8	5.7	44.8	16.1	3.3
YPW	Sika Deer	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.7	-20.1	4.0	45.3	16.2	3.3
M2004	Cattle	Zhou Dynasty (Late Western-Early Eastern)	Tomb	6.2	-12	5.1	45.1	16.3	3.2
M2003	Cattle	Zhou Dynasty (Late Western-Early Eastern)	Tomb	5.5	-17	6.6	45.3	16.4	3.2
T0204(2)	Cattle	Zhou Dynasty (Late Western-Early Eastern)	Fill	2.8	-23.1	3.6	44.8	16	3.3
T0203(2)	Cattle	Zhou Dynasty (Late Western-Early Eastern)	Fill	0.6	-22.9	3.7	44.2	15.7	3.3
T0102(2)	Cattle	Zhou Dynasty (Late Western-Early Eastern)	Fill	0.5	-14.4	6.0	44.3	15.6	3.3
T0202(9)	Cattle	Zhou Dynasty (Late Western-Early Eastern)	Fill	2.5	-17.7	6.5	44.6	15.9	3.3
H1004	Cattle	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.5	-13.7	6.2	44.8	16.2	3.2

M1007	Sheep	Zhou Dynasty (Late Western-Early Eastern)	Tomb	4.6	-17.6	7.0	44.7	16.1	3.3
H1170	Sheep	Zhou Dynasty (Late Western-Early Eastern)	Fill	0.6	-18.9	5.3	44.1	15.7	3.3
T0205	Sheep	Zhou Dynasty (Late Western-Early Eastern)	Fill	2.2	-19.4	9.4	44.3	16.2	3.2
H1004(2)	Sheep	Zhou Dynasty (Late Western-Early Eastern)	Fill	4.7	-18.1	6.2	44.7	15.7	3.3
H1063(5)	Sheep	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.7	-18	5.4	46.9	16.1	3.4
H1167	Goat	Late Neolithic	Fill	0.6	-18.6	5.3	40.9	14.2	3.4
H4028	Goat	Zhou Dynasty (Late Western-Early Eastern)	Fill	2.9	-18.1	6.1	44.6	15.9	3.3
M1007	Goat	Zhou Dynasty (Late Western-Early Eastern)	Tomb	4.1	-19.5	7.3	45	15.7	3.3
H1091	Goat	Zhou Dynasty (Late Western-Early Eastern)	Fill	4.0	-18.5	5.9	45.5	16	3.3
H1170	Goat	Zhou Dynasty (Late Western-Early Eastern)	Fill	1.0	-19.5	8.1	44.4	15.8	3.3
H1107	Dog	Late Neolithic	Fill	0.7	-12.5	8.0	44.7	15.5	3.4
H1102	Dog	Late Neolithic	Fill	0.8	-14.4	8.5	44.4	14.9	3.5
M2003	Dog	Zhou Dynasty (Late Western-Early Eastern)	Tomb	4.1	-14	6.8	44.8	16	3.3
H1004(2)	Dog	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.5	-10.4	10.2	45	15.9	3.3
H4002(3)	Dog	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.2	-13.1	8.9	44.9	16.1	3.3
H1063 STC	Dog	Zhou Dynasty (Late Western-Early Eastern)	Fill	1.3	-9.4	8.1	44.6	15.7	3.3
H1063(2)	Dog	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.9	-9.9	8.8	45.1	16	3.3
H1063(2) ZT	Dog	Zhou Dynasty (Late Western-Early Eastern)	Fill	4.9	-8.1	8.9	45.8	16.3	3.3
M1002	Dog	Zhou Dynasty (Late Western-Early Eastern)	Tomb	2.7	-11.4	10.9	43.7	15.8	3.2
H1002	Pig	Late Neolithic	Fill	1.5	-14.5	7.8	45	15.7	3.4
H1063 BSTC	Pig	Zhou Dynasty (Late Western-Early Eastern)	Fill	2.1	-11	8.1	44.7	15.6	3.3
H1063(2)	Pig	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.6	-8.7	7.5	44.9	15.8	3.3
T0205(2)	Pig	Zhou Dynasty (Late Western-Early Eastern)	Fill	1.3	-11.8	7.9	44.7	15.5	3.4
H1041	Pig	Zhou Dynasty (Late Western-Early Eastern)	Fill	0.9	-17.7	4.9	44.3	15.5	3.3
T0204(2)	Pig	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.1	-9.9	7.8	44.6	15.6	3.3
H1063(2)	Pig	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.1	-9.5	6.5	45	15.8	3.3
H1049	Pig	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.7	-18.8	5.2	45.1	16	3.3

H4029	Pig	Zhou Dynasty (Late Western-Early Eastern)	Fill	4.2	-17.5	5.2	45.2	15.9	3.3
H4002(3)	Bear	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.3	-19.7	2.0	44.9	15.9	3.3
H1003(7)	Unidentified	Zhou Dynasty (Late Western-Early Eastern)	Fill	3.3	-7.3	10.1	45.1	16.1	3.3
H4002(4)	Unidentified	Zhou Dynasty (Late Western-Early Eastern)	Fill	5.1	-18.7	6.7	45.1	16	3.3
T0905(9)	Unidentified	Zhou Dynasty (Late Western-Early Eastern)	Fill	1.5	-12.8	8.5	43.3	15.6	3.2
T0204(3)	Unidentified	Zhou Dynasty (Late Western-Early Eastern)	Fill	0.6	-18.9	7.0	43.4	15.4	3.3
Samples below failed to produced collagen									
T0302	Horse	Zhou Dynasty (Late Western-Early Eastern)	Fill		--	--	--	--	--
M1	Horse	Zhou Dynasty (Late Western-Early Eastern)	Tomb		--	--	--	--	--
M3001P	Deer	Zhou Dynasty (Late Western-Early Eastern)	Tomb		--	--	--	--	--
H3011	Cattle	Zhou Dynasty (Late Western-Early Eastern)	Fill		--	--	--	--	--
H0308(3)	Cattle	Zhou Dynasty (Late Western-Early Eastern)	Fill		--	--	--	--	--
T0102(4)	Pig	Late Neolithic	Fill		--	--	--	--	--

Table 5.2. Isotopic results and sample information for all humans from the Xishan site, Gansu Province, China.

Sample	Phase ca. 700 – 400 BC	Sex	Age	%Yield	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	%C	%N	C:N	Grave Goods	Inferred Status
M1009	Zhou Dynasty (Late Western)	F	40-44	1.4	-10.2	9.8	40.3	14.4	3.3	Common pottery	Low
M1014	Zhou Dynasty (Late Western)	F	Adult	0.5	-8.1	9.0	41.8	15.0	3.3	Jade Gui (玉珪)	Medium
M2003 1*	Zhou Dynasty (Late Western)	F	15-16	1.0	-12.4	9.3	44.1	15.5	3.3	Sacrificed victim including a dog buried inside of a separate wooden box	Low
M1001	Zhou Dynasty (Early Eastern)	?	Adult	1.8	-16.2	7.3	44.8	16.2	3.2	Tomb looted	?
M1002	Zhou Dynasty (Early Eastern)	M	20-25	2.7	-11.4	10.9	43.7	15.8	3.2	32 Grave goods including: bronze weapons, jade, common pottery, bone artifacts and a sacrificed dog	High
M1010	Zhou Dynasty (Early Eastern)	F	40-45	1.5	-11.8	10.6	43.6	15.6	3.3	Tomb looted	?
M1013	Zhou Dynasty (Early Eastern)	F	Adult	1.8	-13.6	7.3	42.7	15.5	3.2	Unknown	?
M1016A	Zhou Dynasty (Early Eastern)	M	Adult	1.9	-23.3	5.5	43.4	15.6	3.3	Unknown	?
M1016 B	Zhou Dynasty (Early Eastern)	F	40-45	2.0	-13.1	9.2	43.8	15.7	3.3	Assorted calaite, jade, and stone artifacts, plus common pottery	Medium
M1020	Zhou Dynasty (Early Eastern)	M	45-50	4.9	-8.6	9.0	45.1	16.2	3.2	Common pottery	Low
M1021	Zhou Dynasty (Early Eastern)	?	8-10	2.2	-19.2	4.6	43.3	15.7	3.2	Tomb partially looted but some grave goods were still present: 7 stone Gui (石圭), bronze artifacts and a sacrificed dog	High?
M1023	Zhou Dynasty (Early Eastern)	?	11-12	1.9	-8.1	8.5	43.6	15.6	3.3	Common pottery	Low
M1024	Zhou Dynasty (Early Eastern)	M	35+	0.7	-11.3	8.6	42.0	15.0	3.3	Stone Gui (石圭), common pottery and a sacrificed dog.	Medium
M1027 2*	Zhou Dynasty (Early Eastern)	?	11-12	1.6	-13.7	7.3	43.2	15.4	3.2	Sacrificed victim that was buried with a sacrificed dog	Low
M3001	Zhou Dynasty (Early Eastern)	M	20-25	2.4	-15.9	5.7	43.1	15.5	3.2	Tomb partially looted but some grave goods were still present: 4 bone arrowheads, stone artifacts, and common pottery	Medium?
LXD M4002	Zhou Dynasty (Early Eastern)	?	Adult	2.6	-7.1	9.0	43.4	15.6	3.2	?	?
M4004	Zhou Dynasty (Early Eastern)	F	15-16	1.4	-10.1	9.6	44.4	16.0	3.2	Tomb looted	?
LXD M4004 A	Zhou Dynasty (Early Eastern)	?	Adult	0.7	-9.0	8.6	45.0	15.7	3.3	Tomb looted	?
LXD M4004B	Zhou Dynasty (Early Eastern)	?	Adult	0.9	-10.1	9.3	44.1	15.8	3.3	Tomb looted	?
M4005	Zhou Dynasty (Early Eastern)	M	Adult	1.1	-15.6	5.5	44.4	16.0	3.2	?	?
LXD H1070	Zhou Dynasty (Early Eastern)	?	Adult	0.9	-13.9	7.5	43.3	15.5	3.3	Tomb looted	?
LXD H1149	Zhou Dynasty (Late Western-Early)	?	Adult?	1.1	-18.4	7.6	44.6	15.9	3.3	Tomb looted	?

	Eastern										
LXD T0203(5)	Zhou Dynasty (Late Western-Early Eastern)	?	Adult?	1.4	-22.6	5.8	44.0	15.8	3.3	Tomb looted	?
LXD T70905(9)	Zhou Dynasty (Late Western-Early Eastern)	?	Adult?	0.3	-15.3	4.9	43.1	14.7	3.4	Tomb looted	?
LXD H4006	Zhou Dynasty (Late Western-Early Eastern)	?	Adult?	2.9	-13.4	8.5	43.9	15.9	3.2	Tomb looted	?
LXD T0201	Zhou Dynasty (Late Western-Early Eastern)	?	Adult?	0.6	-12.4	8.5	44.0	15.0	3.4	?	?
LXD T0203A	Zhou Dynasty (Late Western-Early Eastern)	?	Adult?	1.9	-13.6	5.3	43.8	15.8	3.2	?	?
LXD T0105	Zhou Dynasty (Late Western-Early Eastern)	?	Adult?	0.3	-10.5	9.7	42.0	14.7	3.3	?	?
LXD T0203B	Zhou Dynasty (Late Western-Early Eastern)	?	Adult?	0.7	-19.5	4.3	43.4	15.6	3.3	?	?
LXD T0105(3)	Zhou Dynasty (Late Western-Early Eastern)	?	Adult?	0.3	-10.7	9.2	41.3	14.1	3.4	?	?
LXD T0409(2) A	Zhou Dynasty (Late Western-Early Eastern)	?	Adult?	3.7	-15.6	5.5	43.0	15.6	3.2	?	?
LXD T0409(2) B	Zhou Dynasty (Late Western-Early Eastern)	?	Adult?	2.9	-17.6	7.0	46.6	16.0	3.2	?	?
LXD H1166	Zhou Dynasty (Late Western-Early Eastern)	?	Adult?	3.2	-21.0	4.5	45.1	15.8	3.3	Tomb looted	?
#M2003 2*	Zhou Dynasty (Late Western)	F	30	--	-12.2	9.7	42.8	15.5	3.2	Sacrificed victim, buried in a wood chest with 6 shells, and a jade Han (玉晗). This suggest a close relationship with the tomb owner	High
#M2004	Zhou Dynasty (Late Western)	M	17-19	--	-12.6	9.0	42.7	15.5	3.2	Common pottery	Low
#M1011	Zhou Dynasty (Early Eastern)	M	60+	--	-13.7	8.8	41.9	15.1	3.2	Tomb looted	?
#M1015	Zhou Dynasty (Early Eastern)	M	18-19	--	-14.1	7.7	43.0	15.6	3.2	5 pieces of common pottery	Low
#M1017	Zhou Dynasty (Early Eastern)	F	25-30	--	-11.8	9.4	42.3	15.4	3.2	Common pottery	Low
#M1022	Zhou Dynasty (Early Eastern)	F	51-60	--	-13.2	8.7	41.6	14.8	3.3	Common pottery	Low
#M1027	Zhou Dynasty (Early Eastern)	F	45-50	--	-9.1	10.0	41.2	15.1	3.2	Tomb owner buried with two sacrificed victims, a sacrificed dog, two cattle skulls and other assorted animals. 15 pieces of common pottery, 9 jade pieces (1 Jue 玉珎 and 8 Han 玉晗), and 3 shells.	High
#M1027 1*	Zhou Dynasty (Early Eastern)	F	16-17	--	-8.9	9.6	42.0	15.4	3.2	Sacrificed victim buried in	Low

										wooden coffin	
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* = Sacrificial victim

= Data from Wei, 2008.

CHAPTER 6 Tracing the Locality of Prisoners and Workers at the Mausoleum of Qin Shi Huang: First Emperor of China (259-210 BC)

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Abstract

The mausoleum complex of the First Emperor of China, Qin Shi Huang (259-210 BC), is one of the most famous and important archaeological sites in China, yet questions remain as to how it was constructed and by whom. Here we present isotopic results of individuals from the Liyi (n=146) and Shanren sites (n=14), both associated with the mausoleum complex. Those buried at Liyi represent the local workers/inhabitants of the Qin population, and the $\delta^{13}\text{C}$ ($-8.7\pm 1.5\text{‰}$) and $\delta^{15}\text{N}$ ($10.3\pm 0.7\text{‰}$) values indicate that they consumed predominately millet and/or domestic animals fed millet. In contrast, the Shanren individuals were prisoners forced to construct the mausoleum (found buried haphazardly in a mass grave and some in iron leg shackles), and their $\delta^{13}\text{C}$ ($-15.4\pm 2.9\text{‰}$) and $\delta^{15}\text{N}$ ($8.0\pm 0.6\text{‰}$) results indicate a more mixed C_3/C_4 diet, with possibly less domestic animals and more wild game protein consumed. This pattern of decreased millet consumption is also characteristic of archaeological sites from southern China, and possible evidence the Shanren prisoners originated from this region (possibly the ancient Chu state located in modern day Hubei Province and parts of Hunan and Anhui Provinces). Further, this finding is in agreement with historical sources and is supported by previous ancient DNA evidence that the mausoleum workers had diverse origins, with many genetically related to southern Chinese groups.

6.1 Introduction

As the First Emperor of China, Qin Shi Huang (259-210 BC), brought to conclusion the tumultuous Warring States Period (475-221 BC) and successfully established the first unified Empire of China: the Qin Dynasty^{1,2}. The magnificent mausoleum complex of Qin Shi Huang (including the life sized Terracotta Warrior Army) is considered one of the most important archaeological sites of China, and has been described as the 8th of wonder of the world³. Chinese historical records indicate that as soon as Qin Shi Huang gained control of the Qin State (246 BC), he started building the mausoleum at the northern portion of Lishan Mountain⁴, near the present day city of Xi'an (Figure 6.1). Massive amounts of planning, labor and capital were diverted to the construction of the mausoleum complex, and the entire project took thirty-nine years to complete⁵⁻⁷. In 231 BC, Qin Shi Huang commissioned the building of the city of Liyi (丽邑) to serve as the base of operations for the construction efforts of the mausoleum^{4,8}.⁹ Historians estimate it had a population of approximately a hundred thousand individuals, and it was divided into several neighborhoods such as Xi (戏) and Jiao (焦)⁸⁻¹⁰. Inscriptions on pottery were found at many sites around the mausoleum, verifying that the inhabitants of Liyi City produced a large quantity of domestic earthenware, brick, tile, and other goods used in both the construction of the tomb and the daily life of the town^{11,12}. The Chinese historian, Sima Qian (ca. 145-90 BC), wrote that ~700,000 laborers were requisitioned from all over China to toil in the mausoleum over the course of its construction⁴, and that the workers consisted of skilled craftsmen as well as prisoners (captured warriors and/or criminals) and the indebted (people working to pay taxes)^{13,14}. However, since the Qin Dynasty covered a vast area and included a diverse population of ~20 million people^{15,16}, the origins of the individuals that comprised this massive labor force are not fully known.

This topic has become an important focus of investigation with archaeologists studying writings on pottery tiles found with the burials of the workers as well as inscriptions on some of the Terracotta soldiers for clues about the people that made them¹⁷⁻¹⁹. In addition, recent mtDNA evidence suggests the workers had diverse genetic backgrounds from different regions in China²⁰. Here we present the first research that isotopically examines the dietary habits of the workers/craftsmen from the public cemetery of Liyi, and the prisoners from the mass grave at Shanren that constructed the famous Qin Shi Huang Mausoleum (see supplementary information for more site details). In addition, these results are compared to other contemporary

and earlier sites from across north and south China, and this isotopic information is used in combination with the archaeological evidence and previous mtDNA research²⁰ to better understand the diets and possible geographic origins of these individuals.

6.2 Results

The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results of the fauna and humans are presented in Tables 6.S1 and 6.S2 and plotted in Figure 6.2. The preservation of bone collagen in human and faunal samples was variable. Of the bones prepared, 161 out of 223 humans and 8 out of 9 faunal samples yielded collagen. The %C, %N and atomic C:N together with collagen yields were used to determine the quality of collagen preservation and assess the effects of diagenesis^{21,22}. The collagen yields obtained in the present study were low overall, due to the removal of small degraded collagen fragments during the ultrafiltration step²³, but all samples that produced collagen had C:N values that fell within the range of 2.9–3.6, considered acceptable for stable isotope analysis^{24,25}.

6.2.1 Isotopic data for Liyi humans

The Liyi humans ($n = 146$) show a large variation of isotopic values across the entire population, with the $\delta^{13}\text{C}$ values ranging from -16.3‰ to -7.0‰ (mean = $-8.7 \pm 1.5\text{‰}$) and the $\delta^{15}\text{N}$ values ranging from 6.1‰ to 12.3‰ (mean = $10.3 \pm 0.7\text{‰}$) (Figure 6.2). The majority of individuals have $\delta^{13}\text{C}$ ($> -12.0\text{‰}$) and $\delta^{15}\text{N}$ ($> 9.0\text{‰}$) results indicative of a predominately C_4 diet that was derived from domestic animal proteins (likely pig, cattle, sheep, dog; Figure 6.2). However, several individuals have relatively ^{13}C -depleted values, evidence that they consumed a mixed C_3/C_4 protein diet. In addition, a single individual (M71) plots well away from the population with a ^{13}C -depleted measurement (-16.3‰) as well as the most ^{15}N -depleted result (6.1‰) of all the humans analyzed, suggesting a unique dietary pattern.

6.2.2 Isotopic data for Shanren humans

The Shanren humans ($n = 14$) have $\delta^{13}\text{C}$ values that range from -18.2‰ to -8.5‰ , with a mean value of $-15.4 \pm 2.9\text{‰}$ and $\delta^{15}\text{N}$ results that range from 7.2‰ to 10.8‰ , with a mean value of

8.0±0.6‰ (Figure 6.2). The isotopic results for 12 of the humans (except for M101, M111) cluster in a group (mean values, $\delta^{13}\text{C} = -16.4 \pm 1.1\text{‰}$; $\delta^{15}\text{N} = 8.0 \pm 0.6\text{‰}$). The range of $\delta^{13}\text{C}$ results fall within the expected values of a population consuming both C_3 and C_4 resources, but are closer to values expected for a purely terrestrial C_3 protein diet. In contrast, the individuals M101 and M111 have significantly ^{13}C -enriched results reflecting that the protein portions of their diets were predominately C_4 either from plants (M111, low $\delta^{15}\text{N} = 7.6\text{‰}$) or from animals that were feeding on C_4 plants (M101, high $\delta^{15}\text{N} = 10.8\text{‰}$).

6.3 Discussion

Substantial research on the agricultural practices of northern China, as well as archaeological evidence from pollen, phytolith and plant flotation studies found that millet agriculture was established in northern China and became the dominant grain for human food or for animal fodder in the late Neolithic^{26, 27}. In this study, the isotopic evidence indicates that millet was the most important crop for the daily diet of the Liyi population during the Qin period. This finding is also supported by previously published isotopic data of contemporary sites from the Guanzhong Plain (an area central to the original Qin state)^{4, 28} (Table 6.1). There are no large isotopic differences between these sites (Figure 6.3), and nearly all of the north Chinese populations had diets that were predominately based on millets with varying amounts of domestic animal protein consumption (Figure 6.3).

The human mean $\delta^{15}\text{N}$ value (10.3±0.7‰) indicates a significant consumption of domestic animal protein for the Liyi population as a whole, but individual differences exist (Figure 6.2). In comparison with the fauna data, the offsets in the $\delta^{13}\text{C}$ values between the humans and the chicken/crane indicate that these species were not the main sources of protein for the population. In addition, the Liyi population is significantly elevated (one-way ANOVA; $p = 0.000$) in mean $\delta^{15}\text{N}$ compared to the contemporary period Qin sites of Sunjianantou ($\delta^{15}\text{N} = 8.5 \pm 1.0\text{‰}$)²⁹ and Jianhe ($\delta^{15}\text{N} = 8.7 \pm 0.5\text{‰}$)³⁰, which might indicate that the Liyi people consumed more animal protein in their diet than other Qin sites (Figure 6.3). However, due to the small number of faunal samples, we caution against more detailed interpretations.

Historical sources such as *Shijing* (诗经)³¹, *Liji* (礼记)³², and *Zhouli* (周礼)³³ provide important accounts concerning the diet during the pre-Qin period. Millet, soybean and wheat were

discussed as the main crops in the central plains region of China before the Han dynasty. In particular, the *Shuihudi Qin bamboo texts* (睡虎地秦简), (written during the Qin Dynasty, recording Qin laws and public documents, and excavated from a Qin tomb in Yunmeng County, Hubei Province in 1975)³⁴ described that the Qin State stored a large amount of millet in the capital's granary. In *Shiji* (史记), Sima mentioned that the Qin people avoided the consumption of soybean because they viewed it as a crop for the poor and were also uninterested in the planting of wheat⁴. Thus, the isotopic results presented here, that the Qin diet was heavily reliant on millet, are in agreement with the Chinese historical texts. The typical Qin diet was also described as including a number of possible meat sources: cattle, sheep, goat, dog as well as wild boar³⁵⁻³⁷. Sima wrote that there were special shops to sell dried and spiced meats in the city of Xianyang, the capital of the Qin⁴. In addition, *Shiji* (史记) and *Hanshu* (汉书) also mentioned that dog meat consumption was prevalent during the Qin and Han Dynasties, since many people made their living by the butchering dogs.^{4, 38}

In contrast to Liyi, the $\delta^{13}\text{C}$ values for the Shanren humans were variable but show a diet reliant on mixed C_3/C_4 protein sources, involving the consumption of millet or animals fed millet and possibly rice and/or wheat or wild game over their lifetime (Figure 6.2). However, two individuals (M101 and M111) ate predominately C_4 -based foods, and one individual (M113) consumed predominately C_3 -based foods. The $\delta^{15}\text{N}$ values exhibit a narrow range ($\pm 1\text{‰}$) for all individuals (except M101), and were similar or only slightly elevated above the local animal species. This possibly suggests these people were consuming less animal protein compared to the population at Liyi which agrees with the fact that these mausoleum workers were of lower status (likely prisoners since buried with iron leg shackles in a mass grave without grave goods; see supplementary section) than the villagers.

Additional evidence to support this possibility comes from historical sources. The *Shuihudi Qin bamboo texts* (睡虎地秦简) recorded that prisoners were provided food according to their assignments, with workers that built walls or engaged in heavy manual labor receiving ~0.75 kg and ~0.5 kg of rough millet for lunch and dinner, respectively³⁴. Since meat and wine were only given to soldiers as a reward, it is unlikely that domestic animal meat was part of a prisoner's daily diet³⁴. However, it is possible that these prisoners could have supplemented their daily diet with wild game. It is interesting to note that only a single individual (M101) was observed to have isotopic values identical to the Liyi population. Thus, it is possible this

person could have been a townspeople that was forced to labor in the mausoleum construction as a result of punishment or to pay back a debt. However, if many of the Shanren individuals were not locals and were from other regions of China, then these lower isotopic values would reflect the local environmental food web from where they originated, and this possibility is considered below.

While the archaeobotanical remains of rice and wheat have been discovered at many sites in northern China since at least the end of the Neolithic³⁹⁻⁴³, archaeological research indicates that distinct dietary differences existed between north (millet) and south (rice) China with the overlapping regions designated as rice-millet blended zones⁴⁴. Current isotopic findings focused on $\delta^{13}\text{C}$ human values support that these general dietary differences existed at the population level between sites in north (C_4 = millet) and south (C_3 = rice) China (see Table 6.1; Figures 6.1a, 6.3). These isotopic dietary differences between north and south China can be used as markers to examine the general origins of the Shanren individuals, who died constructing the Mausoleum of Qin Shi Huang. Specifically, evidence from a number of previous isotopic studies in China are used for comparison to the Shanren results (Figure 6.3).

All the Western and Eastern Zhou period sites from north China display evidence of significant millet consumption^{29, 30, 45-47} (Figures 6.1a, 6.3; Table 6.1). For instance, in Shanxi Province, Pei et al.⁴⁶ suggested that the Neiyangyuan people mainly relied on stockbreeding, and the high C_4 signatures in the $\delta^{13}\text{C}$ values shows that the consumption of millet made a significant contribution to the diet by direct consumption and/or as fodder for their livestock. The isotopic results for people from the eastern Province of Shandong also show a reliance on millet^{27, 48-50}, but the Neolithic Xigongqiao population had a mixed C_3/C_4 diet⁵¹. The hot and humid climate of south China is unfavorable for collagen preservation, and this has resulted in significantly less isotopic research in this region. Since only three relatively contemporary sites from south China exist⁵²⁻⁵⁴ (Figure 6.1a; Table 6.1), additional south Chinese isotopic results from earlier periods were used^{50, 55-56}, and we acknowledge and caution that this time difference between sites is not ideal for direct comparison. Still, by examining the south China $\delta^{13}\text{C}$ results, it can be seen that nearly all populations were consuming C_3 diets (Figure 6.1a, 6.3).

Unfortunately, no grave goods or pottery tiles with identifying information were found in the Shanren mass grave and other research methods and historical sources are needed to determine

their origins. When both the carbon and nitrogen results of the Shanren individuals are compared to the pre-Qin site of Qianzhangda in Shandong Province (Table 6.1; Figure 6.3), we see there are no similarities, and that the sites are statistically distinct (one-way ANOVA; $p = 0.000$ for $\delta^{13}\text{C}$; $p = 0.000$ for $\delta^{15}\text{N}$). However, the Shanren isotopic results are nearly indistinguishable from the much earlier Neolithic site of Xigongqiao (Figure 6.3). Given the antiquity of Xigongqiao and that there is only a single pre-Qin site (Qianzhangda) from Shandong, it is difficult to determine if the Shanren individuals were originally from the Shandong region, but this is a possibility since archaeobotanical studies have found evidence for populations with rice economies in this region^{39, 41}. Thus, additional isotopic studies focused on Qin period archaeological sites from Shandong are necessary to provide more information.

Compared to the local Liyi population, the Shanren individuals had a mixed diet of millets or animals consuming millets and possibly rice and/or wheat and appear to have consumed less animal products. This decrease in millet consumption appears to correspond with the isotopic results of people from the southern areas of China. Given that both the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for the Shanren humans are similar to the contemporary Qinglongquan site in Hubei Province (Figure 6.3) this could suggest that many of the Shanren individuals came from the same general region. However, there are outliers, with the individual M101, having nearly identical isotopic results as the Liyi population, strongly suggesting that he was from the local area. In addition, M111 had a similar $\delta^{13}\text{C}$ value to the Liyi individuals but a significantly lower $\delta^{15}\text{N}$ value. This could suggest two potential possibilities: he was from the Liyi area but consuming millet with little animal protein (a prisoner's diet) or that he was from another area of northern China that was distinct from the Liyi community.

Excavations at the Zhaobeihu site (another contemporary cemetery consisting of mausoleum prisoners) discovered several fragments of pottery tile with epitaphs that recorded personal information (e.g. names, ranks, birthplaces) about these people and confirm that these prisoners were from distant regions of China^{58, 59}. In particular, these writings show that seventeen individuals were from the eastern region of the Qin State from today's Shandong Province ($n = 10$), Jiangsu Province ($n = 1$), Henan Province ($n = 3$) and Hebei Province ($n = 3$)¹⁷. This suggests that the prisoners were kept as a group and buried together by their rank and general regions of origin (similar language, customs, diet, etc.).

Additional evidence is provided by past ancient DNA analysis. Xu et al.²⁰ also studied the mtDNA from nineteen workers from the Shanren site, and concluded that many of these people were Hans or minorities from the south of China. Unfortunately, due to different individuals being selected, a direct comparison between the ancient DNA and the isotopic results is only possible for a single individual (M91). M91 had a mixed C₃/C₄ δ¹³C signature (-17.1‰) that is suggestive of southern China (Figure 6.3), and this agrees with the ancient DNA findings that he was genetically related to the southern Han people.²⁰ However, since the study of Xu et al.²⁰ compared the Shanren remains to modern individuals, some skepticism and caution about the results is warranted. There is the possibility that later migrations and admixture between the populations of north and south China could complicate the understanding of the genetics from the archaeological individuals. However, bearing this possibility in mind, our isotopic results suggest that many of the Shanren prisoners had isotopic signatures for mixed C₃/C₄ diets found in southern China, and these results are in agreement with the genetic findings of Xu et al.²⁰

Finally, according to historical documents that describe the wars and battles of the Qin State^{4, 13}, a southern origin for these Shanren prisoners, forced to construct the Qin Shi Huang Mausoleum, is certainly plausible given the other lines of evidence presented here. Thus, we can further hypothesize that these Shanren individuals were possibly from the rival Chu state, located in modern-day Hubei Province, as well as northern Hunan and southern Anhui Provinces (Figure 6.1). In conclusion, while limited and far from perfect, the isotopic results presented here are able to lend some support to the ancient DNA evidence and historical sources, highlighting the benefits of stable isotope studies to document migration in archaeological populations in China.

6.4 Methods

A total of 223 individuals consisting of rib and long-bone fragments were obtained from the Liyi cemetery, from both the “Xinfeng” (n=166) and “Wanli” sites (n=57). Fauna samples (pig, dog, cattle, sheep, chicken and crane; n=9) found in the “Wanli” site during excavation were also collected and analyzed. In addition, human remains (n=19) consisting of rib and long-bone

fragments were sampled from the Shanren site¹⁹. Additional details about the fauna and humans can be found in Table 6.S1 and 6.S2, respectively.

Collagen samples were prepared following the protocol outlined in Richards and Hedges⁶⁰ modified by using the ultrafiltration method^{61, 62}. Small bone chunks were cleaned by air abrasion and then demineralized at 4 °C in 0.5 M HCl for two weeks. Once demineralized, the samples were rinsed three times with deionized water, and then introduced to a pH=3 solution and gelatinized at 70 °C for 48 hours. The samples were first filtered with a 5µm EZEE[®] filter to remove the insoluble residues; then ultrafiltered (Amicon[®] ultrafilters <30 kDa), and finally the purified collagen was frozen and freeze dried for 2 days. About 0.5 mg of dried collagen was weighed into tin capsules for analysis and each sample was measured in duplicate using a Flash EA 2112 coupled to a Delta XP mass spectrometer (Thermo-Finnigan[®], Bremen, Germany). Natural abundance of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ is expressed as ‘per mil’ (‰) with respect to international standards: $\delta^{13}\text{C}$ or $\delta^{15}\text{N} = (\text{R}_{\text{sample}}/\text{R}_{\text{standard}} - 1) * 1000$, where R in $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ is $^{13}\text{C}/^{12}\text{C}$ or $^{15}\text{N}/^{14}\text{N}$, respectively. Vienna Pee Dee belemnite (VPDB) and atmospheric nitrogen (AIR) were used as the international standards for carbon and nitrogen, respectively. The analytical precision was $\pm 0.2\text{‰}$ for both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$.

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6.6.1 Author contributions

Y.M., B.T.F., Y.H. and M.P.R. designed the research and analyzed data. Y.M. performed experiments. W.S., S.H. and L.C. provided materials and resources. S.H. identified the fauna species. Y.M., B.T.F. and Y.H. wrote the paper.

6.6.2 Competing financial interests:

The authors declare no competing financial interests.

6.7 Tables

Table 6.1. Summary of isotopic results from the Liyi and Shanren sites as well as from the previous published pre-Qin and Qin populations from north and south China.

Site	# Humans	$\delta^{13}\text{C} \pm \text{SD}$ (‰)	$\delta^{15}\text{N} \pm \text{SD}$ (‰)	Period	Age	Location	Modern Chinese Province	Reference
Sunjianantou	25	-10.8±1.3‰	8.5±1.0‰	Eastern Zhou	ca. 770-221	North China	Shaanxi	29
Jianhe	14	-9.2±0.7‰	8.7±0.5‰	Late Eastern Zhou	ca. 476-221	North China	Shaanxi	30
Zhouyuan	10	-9.3±1.0‰	9.1±1.4‰	Western Zhou	ca. 1046-771	North China	Shaanxi	45
Liangdaicun	7	-8.5±0.6‰	9.7±0.7‰	Western Zhou	ca. 1046-771	North China	Shaanxi	45
Neiyangyuan	22	-8.3±0.7‰	9.5±1.0‰	Late Eastern Zhou	ca. 476-221	North China	Shanxi	46
Tunliuyuwu	6	-9.7±1.6‰	8.8±0.6‰	Late Eastern Zhou	ca. 476-221	North China	Shanxi	47
Qianzhangda	26	-9.2±1.4‰	10.0±1.3‰	Western Zhou	ca. 1046-771	North China	Shandong	48
Liangchengzhen	15	-9.8±2.0‰	--	Neolithic	ca. 2500-2000	North China	Shandong	27
Beiqian	20	-9.2±0.7‰	8.1±0.1‰	Neolithic	ca. 6100-5500	North China	Shandong	49
Guzhendu	4	-8.4±0.7‰	9.6‰*	Neolithic	ca. 4300-2500	North China	Shandong	50
Xigongqiao	8	-15.0±3.9‰	8.4±1.3‰	Neolithic	ca. 5000-4500	North China	Shandong	51
Qinglongquan	9	-14.5±1.1‰	7.1±1.0‰	Eastern Zhou	ca. 770-221	South China	Hubei	54
Sanxingcun	19	-20.1±0.2‰	9.7±0.3‰	Early Neolithic	ca. 6500-5500	South China	Jiangsu	55
Tianluoshan	10	-20.7±0.5‰	8.7±0.9‰	Early Neolithic	ca. 7000-5500	South China	Zhejiang	56
Hemudu	4	-18.2±2.2‰	11.4±0.3‰	Early Neolithic	ca. 6800-6000	South China	Zhejiang	50
Songze	2	-19.9±0.4‰	10.9±1.6‰	Early Neolithic	ca. 5800-4900	South China	Shanghai	50
Tashan	3	-18.4±0.5‰	9.2±0.7‰	Early Neolithic	ca. 5900-5600	South China	Zhejiang	56
Liyudun	2	-17.0±1.3‰	13.8±1.4‰	Early Neolithic	ca. 7000-6000	South China	Guangdong	57
Jinlianshan	9	-18.8±0.4‰	9.8±0.9‰	Late Eastern Zhou	ca. 476-221	South China	Yunnan	53
Puge	1	-20.4‰	--	Late Eastern Zhou	ca. 476-221	South China	Sichuan	52

*= only one sample measured for nitrogen

6.8 Figures

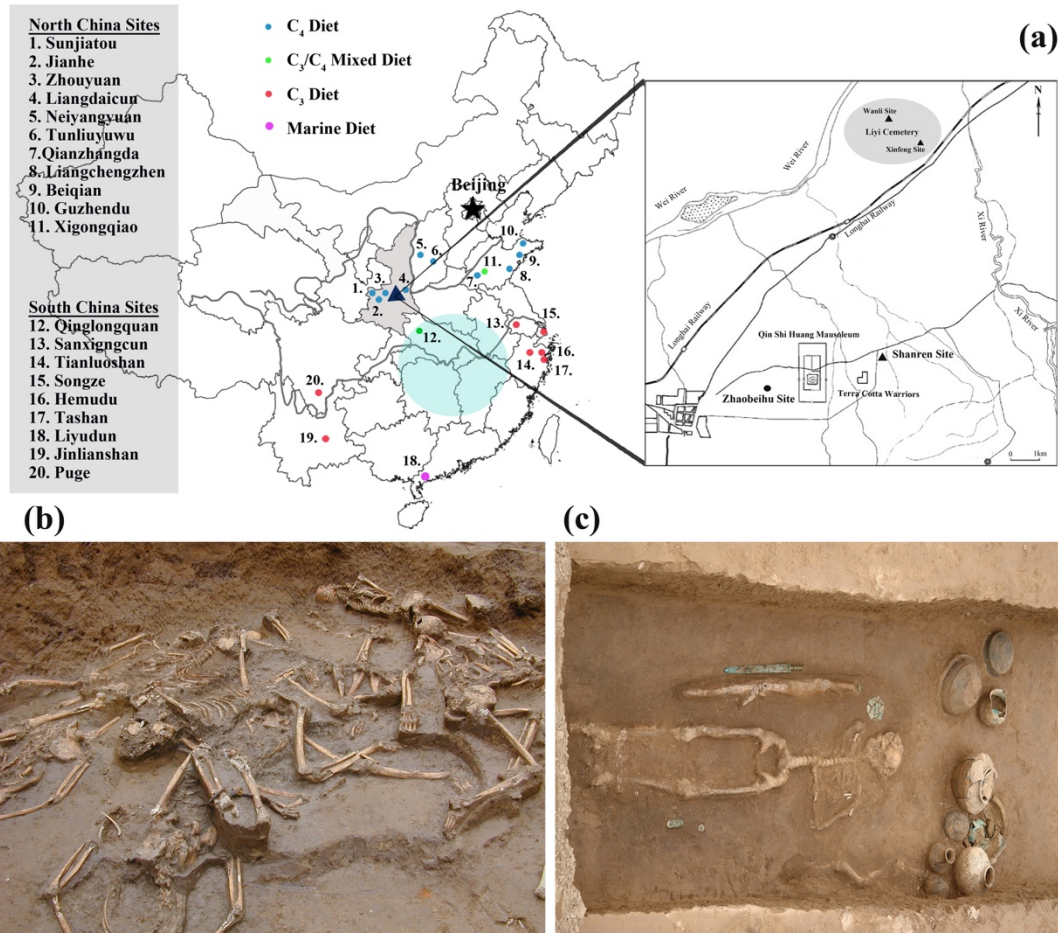


Figure 6.1. a) Map of mainland China showing the location of the Shanren and Liyi sites in Shaanxi Province (shaded) and the additional archaeological sites mentioned in the text. Shaded circle represents an estimate of the original Chu state from which the mausoleum workers may have originated. (Map was created by the authors, Ying Ma and Weigang Sun, using MATLAB and CorelDRAW) b) Picture showing the excavation of the mausoleum workers from the Shanren site. c) Picture showing the burial of one of the Liyi individuals (Note: the bronze sword and ceramic pottery grave goods). (Pictures b and c were taken by the author, Weigang Sun).

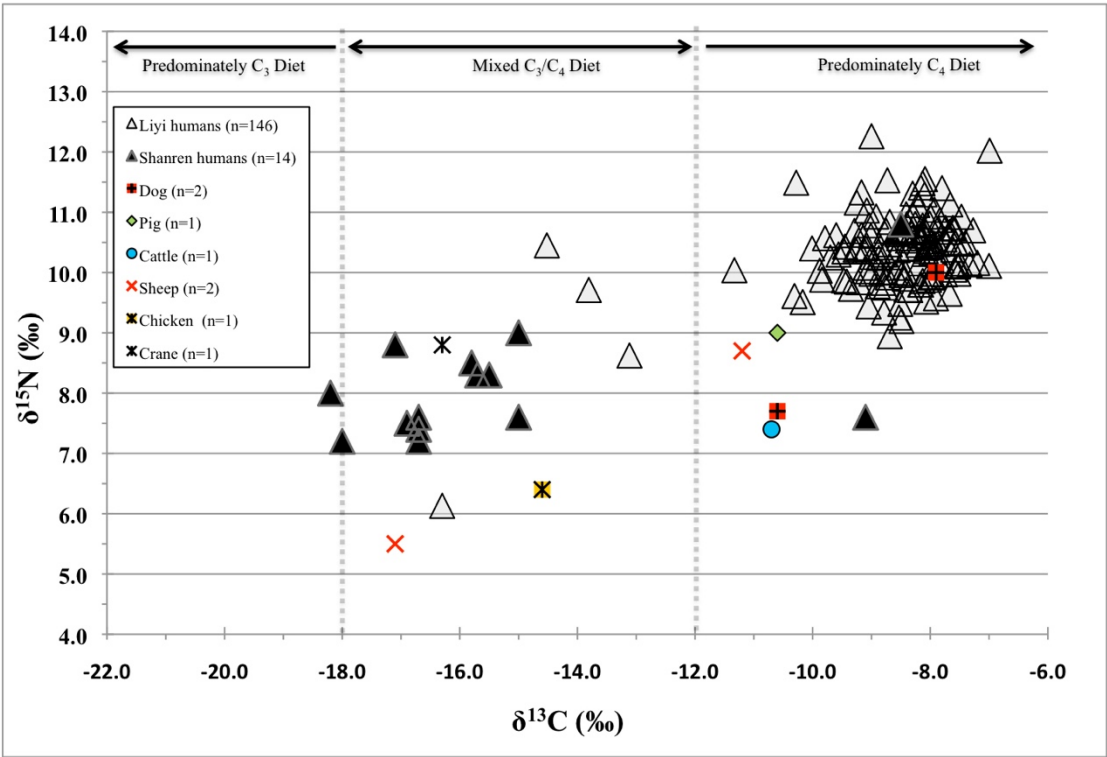


Figure 6.2. Human and animal $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from the Liyi and Shanren sites.

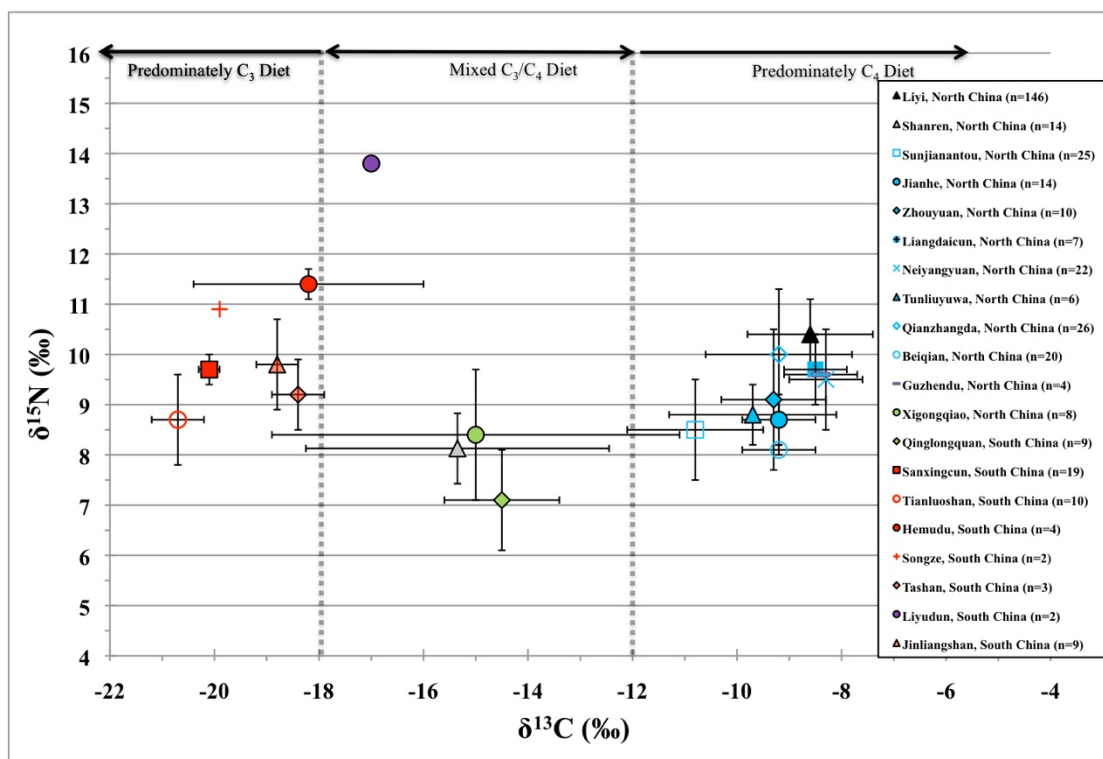


Figure 6.3. Human $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values (mean \pm sd) from the Liji and Shanren sites, and the previous published isotopic results from pre-Qin and Qin populations in north and south China.

6.9 Supplementary Information

6.9.1 Isotopic analysis and palaeodietary reconstruction

Carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) stable isotope ratio analysis is used to investigate a wide range of topics such as subsistence patterns, mobility, health and nutrition, weaning age, and the social stratification of past populations¹⁻¹¹. The distinct advantage of this method is that it provides direct evidence about the type of foods that were actually eaten by an individual. Therefore, using stable isotope analysis on archaeological remains, it is possible to examine the dietary contributions of distinctive food groups, and then identify individuals or populations by dietary diversity.

The $\delta^{13}\text{C}$ values can differentiate between C_3 and C_4 terrestrial diets in humans and animals. Different photosynthetic pathways used by C_3 plants (including most vegetables, rice, wheat, and barley), and C_4 plants (including millet, maize and some tropical grasses), lead to distinct $\delta^{13}\text{C}$ values. For instance, rice has a $\delta^{13}\text{C}$ value averaging about -26‰ , whereas the $\delta^{13}\text{C}$ values for millet are about -11.8‰ ¹². Experimental evidence from controlled feeding experiments with rodents suggests that isotopes in bone collagen primarily represent a consumer's protein sources, and that there is $\sim 5\text{‰}$ $\delta^{13}\text{C}$ shift between diet and consumer bone collagen^{13, 14}. The $\delta^{13}\text{C}$ measurement of animal and human remains has been used to successfully reconstruct the spread of C_3 and C_4 agriculture and animal husbandry practices from sites across China^{12, 15-18}. The $\delta^{15}\text{N}$ values increase by $\sim 3\text{-}5\text{‰}$ per trophic level, principally reflecting the position of an individual in the food chain^{2, 19, 20}. Thus, the type and amount of animal protein in the diet can be estimated for individuals when compared to the animals at an archaeological site. An expanded discussion concerning stable isotope ratio analysis is beyond the scope of this work and the following reviews are recommended for greater indepth reading^{4, 20, 21, 22}

6.9.2 Liyi cemetery site

The Liyi cemetery site is located ~ 6 km southwest of the Qin Shi Huang Mausoleum and ~ 40 km from the city of Xi'an, Shaanxi Province, China (Figure 6.1). From 2007-2010, excavations yielded more than a thousand burials, most of which belonged to the Qin culture and dating from

the late phase of the Warring State Period (476-221 BC) through the entire Qin Dynasty (221-207 BC). The majority of graves were aligned W-E, and contained single inhumations in wooden coffins buried with a flexed posture. An examination of the physical anthropology of the skeletons did not reveal evidence of wounds or trauma indicating that the deaths of the individuals were natural (pers. comm., Liang Chen). Most of the burials had associated grave goods: pottery, bronze sacrificial items, bronze swords and iron tools, but some contained high value objects such as jade, silver, and shell. The site was divided into two parts by the construction of a highway, and was excavated by two teams from the Shaanxi Provincial Institute of Culture Relics and Archaeology. The excavators named one side of the site as “Xinfeng” and the other as “Wanli”. More than 20 pottery tiles with the inscription of the Chinese character “Xi” (戏) were unearthed with the burials, supporting that this site was a public cemetery for the people that lived in the Xi district of Liyi.

6.9.3 Shanren site

In 2003, a Qin Dynasty kiln (Shanren site) was found just 500 meters away from the Terracotta Army Museum, by a team of archaeologists from the Shaanxi Provincial Institute of Culture Relics and Archaeology (Figure 6.1a). Unexpectedly, 121 human skeletons, together with a large number of segmental tiles, iron tools and instruments of torture, were unearthed around the kiln site²³. However, no grave goods or identifying information was found with these individuals. The deceased were buried in a casual manner in a mass grave (some with iron shackles around their legs): stacked layer-upon-layer and thrown into a 10-meter deep pit (Figure 6.1b). Osteological research on the skeletons revealed that all individuals were adult males between 15-45 years old with the average age at death being 24 years²³. In addition, evidence of skeletal trauma and arthritis were found on nearly all the remains, indicating that the individuals were engaged in heavy work before death. Thus, the deceased were presumed to be prisoners and/or criminals that worked to build the mausoleum, and likely died suddenly in an accident or were killed, and quickly buried together.

6.9.4 Faunal isotope data

The two sheep have very different isotopic values (Figure 6.2). One individual has a predominately C₄ diet ($\delta^{13}\text{C} = -11.2\text{‰}$) and the other has a mixed C₃/C₄ diet ($\delta^{13}\text{C} = -17.1\text{‰}$). The $\delta^{15}\text{N}$ values are also different between these two sheep (5.5‰ and 8.7‰), and suggest that they were fed different diets or were possibly grazed at different locations near the site. The two birds (chicken, $\delta^{13}\text{C} = -14.6\text{‰}$, $\delta^{15}\text{N} = 6.4\text{‰}$; crane, $\delta^{13}\text{C} = -16.3\text{‰}$, $\delta^{15}\text{N} = 8.8\text{‰}$) have similar $\delta^{13}\text{C}$ results that reflect a mixed C₃/C₄ diet, but the nitrogen result of the crane is elevated compared to the chicken (Figure 6.2). The pig ($\delta^{13}\text{C} = -10.6\text{‰}$), two dogs ($\delta^{13}\text{C} = -9.3\text{‰}$) and cattle ($\delta^{13}\text{C} = -10.7\text{‰}$) all have the most ¹³C-enriched values and were consuming a predominately C₄ diet of millet (Figure 6.2). One of the dogs has a similar isotopic value to the Liyi population, and its high $\delta^{15}\text{N}$ value (10.0‰) indicates that it was likely feeding on human refuse^{24, 25}. The pig also has an elevated $\delta^{15}\text{N}$ value (9.0‰) that could suggest it was feeding on human waste²⁶. The cow has a lower $\delta^{15}\text{N}$ value (7.4‰) that is similar to the other dog (7.7‰), but it is difficult to comment further as we only have a single individual.

6.9.5 Supplementary References

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6.9.6 Supplementary Tables

Table 6.2S1. Isotopic results and sample information for all fauna from the Liyi cemetery (Wanli), Shaanxi Province, China.

Site	ID #	Taxon	Element	%Yield	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	%C	%N	C:N
Liyi (Wanli)	M122	Pig	Scapula	0.3	-10.6	9.0	38.9	13.8	3.3
Liyi (Wanli)	M24	Dog	Humerus	3.4	-10.6	7.7	45.1	16.4	3.2
Liyi (Wanli)	M111	Dog	Cubitus	1.1	-7.9	10.0	44.3	15.9	3.3
Liyi (Wanli)	M122	Sheep	Vertebra	0.4	-11.2	8.7	45.1	15.8	3.3
Liyi (Wanli)	M37	Sheep	Scapula	4.8	-17.1	5.5	47.1	17	3.2
Liyi (Wanli)	M122	Chicken	Tibia	1.0	-14.6	6.4	44.8	15.8	3.3
Liyi (Wanli)	M122	Crane	Tibia	3.1	-16.3	8.8	45.5	16.4	3.2
Liyi (Wanli)	M111	Cattle	Tibia	2.9	-10.7	7.4	42.5	15.3	3.2
The sample below failed to produced collagen									
Liyi (Wanli)	M85	Horse	Phalanx	--	--	--	--	--	--

Table 6.3S2. Isotopic results and sample information for all humans from the Shanren and Liyi (Xinfeng & Wanli) sites, Shaanxi Province, China.

Site	ID #	Period	Element	Sex	Age	%Yield	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	%C	%N	C:N	Pathology	Grave Goods
Shanren	M91	Qin Ca. 221-207 BC	Tibia	Male	18-22	1.0	-17.1	8.8	43.9	15.5	3.3	Periodontitis, Cubitus fracture	None
Shanren	M92	Qin Ca. 221-207 BC	Humerus	Male	25	0.4	-16.9	7.5	21.5	7.5	3.4	Myositis ossificans, Dental caries	None
Shanren	M93	Qin Ca. 221-207 BC	Humerus	Male	18-20	1.0	-16.7	7.4	43.2	15.4	3.3	Periodontitis	None
Shanren	M96	Qin Ca. 221-207 BC	Tibia	Male	17-18	0.4	-15.7	8.3	40.8	14.2	3.3	Periodontitis	None
Shanren	M99	Qin Ca. 221-207 BC	Femur	Male	25	1.2	-16.7	7.6	44.4	15.9	3.3	Periodontitis Impacted tooth	None
Shanren	M112	Qin Ca. 221-207 BC	Humerus	Male	40	0.7	-16.7	7.2	27.4	9.7	3.3	Periodontitis Periapical abscess	None
Shanren	M101	Qin Ca. 221-207 BC	Tibia	Male	20-25	0.8	-8.5	10.8	42.7	14.8	3.4	Periodontitis	None
Shanren	M102	Qin Ca. 221-207 BC	Rib	Male	17-19	0.4	-18.0	7.2	30.6	10.6	3.4	Unknown	None
Shanren	M103	Qin Ca. 221-207 BC	Tibia	Male	Adult	0.2	-15.8	8.5	17.8	6.4	3.3	Unknown	None
Shanren	M107	Qin Ca. 221-207 BC	Tibia	Male	16-18	0.3	-15.0	7.6	37.9	13	3.4	Impacted tooth	None
Shanren	M108	Qin Ca. 221-207 BC	Rib	Male	18-22	0.3	-15.5	8.3	20.7	7.7	3.1	Periodontitis	None
Shanren	M109	Qin	Femur	Male	25	1.3	-15.0	9.0	28.8	10.7	3.1	Periodontitis	None

		Ca. 221-207 BC										Impacted tooth	
Shanren	M111	Qin Ca. 221-207 BC	Femur	Male	20-22	1.6	-9.1	7.6	36.7	13.5	3.2	Periodontitis	None
Shanren	M113	Qin Ca. 221-207 BC	Tibia	Male	18-20	0.4	-18.2	8.0	30.8	10.9	3.3	Unknown	None
Liyi (Xinfeng)	M66	Qin Ca. 221-207 BC	Tibia	Male	20-25	0.2	-8.1	10.4	14.7	5.3	3.2	Unknown	4 common pottery, 1 bronze belt hook
Liyi (Xinfeng)	M71	Qin Ca. 221-207 BC	Tibia	Male	40-44	0.6	-16.3	6.1	38.1	13.9	3.2	Unknown	7 common pottery
Liyi (Xinfeng)	M72	Qin Ca. 221-207 BC	Femur	Female	45-50	0.7	-8.0	10.4	41.5	15.1	3.2	Unknown	2 common pottery, 2 bronze vessels
Liyi (Xinfeng)	M73	Qin Ca. 221-207 BC	Tibia	Male	30	0.7	-10.3	11.5	33.8	11.7	3.4	Unknown	2 bronze vessels 2 jade objects
Liyi (Xinfeng)	M82	Qin Ca. 221-207 BC	Tibia	Female	24-26	0.2	-9.5	9.9	31.3	11.2	3.3	Unknown	8 common pottery, 8 bronze vessels, 1 bone object
Liyi (Xinfeng)	M94	Qin Ca. 221-207 BC	Tibia	Female	17-19	0.2	-9.0	12.3	13.1	4.7	3.2	Unknown	7 common pottery
Liyi (Xinfeng)	M117	Qin Ca. 221-207 BC	Tibia	Female	>60	0.6	-8.0	10.5	30.7	11.3	3.2	Unknown	9 common pottery
Liyi (Xinfeng)	M131	Qin Ca. 221-207 BC	Tibia	Male	Adult	1.0	-8.3	10.7	30.0	10.9	3.2	Unknown	None
Liyi (Xinfeng)	M136	Qin Ca. 221-207 BC	Tibia	Female	>60	1.2	-7.7	11.1	37.7	13.5	3.2	Unknown	3 common pottery
Liyi (Xinfeng)	M140	Qin Ca. 221-207 BC	Humerus	Female	17-19	0.5	-7.0	10.1	30.8	11.2	3.2	Unknown	9 common pottery, 1 iron object
Liyi (Xinfeng)	M143	Qin Ca. 221-207 BC	Femur	Female	31-34	1.8	-8.7	9.9	28.8	10.2	3.3	Unknown	None
Liyi (Xinfeng)	M145	Qin Ca. 221-207 BC	Humerus	Female	40	8.1	-7.9	10.5	33.4	12.2	3.2	Unknown	7 common pottery, 1 bronze vessel
Liyi (Xinfeng)	M147	Qin Ca. 221-207 BC	Tibia	Female	>60	2.1	-8.1	9.5	24.0	8.6	3.2	Unknown	8 common pottery, 3 bronze vessels
Liyi (Xinfeng)	M154	Qin Ca. 221-207 BC	Tibia	Female	Adult	10.3	-9.8	10.6	36.6	13.4	3.2	Unknown	5 common pottery, 2 bronze vessels

Liyi (Xinfeng)	M157	Qin Ca. 221-207 BC	Femur	Female	50	4.9	-8.5	10.1	40.5	14.8	3.2	Unknown	5 common pottery
Liyi (Xinfeng)	M161	Qin Ca. 221-207 BC	Tibia	Female	51-60	3.1	-10.0	10.4	31.4	11.2	3.3	Unknown	7 common pottery
Liyi (Xinfeng)	M164	Qin Ca. 221-207 BC	Femur	Male	51-60	6.6	-8.8	9.8	21.4	7.7	3.2	Unknown	2 bronze vessels
Liyi (Xinfeng)	M165	Qin Ca. 221-207 BC	Tibia	Female	25-30	3.4	-7.7	9.7	37.8	13.5	3.3	Unknown	None
Liyi (Xinfeng)	M177	Qin Ca. 221-207 BC	Femur	Male	25-30	0.6	-8.7	11.5	41.2	14.6	3.3	Unknown	11 common pottery, 2 bronze vessels, 1 iron object, 1 bone object, 1 stone object, 1 jade object
Liyi (Xinfeng)	M182	Qin Ca. 221-207 BC	Tibia	?	?	8.9	-9.0	10.0	35.3	12.8	3.2	Unknown	None
Liyi (Xinfeng)	M205	Qin Ca. 221-207 BC	Femur	Female	30	5.5	-14.5	10.5	40.4	14.7	3.2	Unknown	2 bronze vessels, 4 jade objects,
Liyi (Xinfeng)	M213	Qin Ca. 221-207 BC	Tibia	Male	45-50	2.8	-8.4	10.7	40.5	14.6	3.2	Unknown	7 common pottery, 1 bronze vessel
Liyi (Xinfeng)	M221	Qin Ca. 221-207 BC	Tibia	Male	Adult	1.4	-8.3	11.0	24.8	9	3.2	Unknown	7 bronze vessels, 2 silver loops
Liyi (Xinfeng)	M228	Qin Ca. 221-207 BC	Femur	Male	31-34	1.9	-9.5	10.4	41.3	14.7	3.3	Unknown	1 bronze vessel
Liyi (Xinfeng)	M231	Qin Ca. 221-207 BC	Tibia	?	?	0.3	-7.6	10.7	25.9	9.5	3.2	Unknown	Unknown
Liyi (Xinfeng)	M244	Qin Ca. 221-207 BC	Tibia	Female	20-23	0.4	-8.2	9.8	43.0	15.5	3.2	Unknown	7 common pottery, 2 bronze vessels, 1 iron object, 1 bone object
Liyi (Xinfeng)	M271	Qin Ca. 221-207 BC	Tibia	Male	60	0.3	-7.5	10.0	24.5	8.9	3.2	Unknown	3 common pottery
Liyi (Xinfeng)	M274	Qin Ca. 221-207 BC	Tibia	Male	Adult	0.2	-7.5	10.1	24.2	8.8	3.2	Unknown	1 common pottery, 2 bronze vessels

Liyi (Xinfeng)	M280	Qin Ca. 221-207 BC	Tibia	Male	Adult	0.3	-8.0	10.8	39.0	13.8	3.3	Unknown	2 common pottery, 1 bronze vessel, 1 iron object
Liyi (Xinfeng)	M281	Qin Ca. 221-207 BC	Femur	Female	35	0.2	-8.5	10.6	33.7	12.1	3.3	Unknown	1 bronze vessel
Liyi (Xinfeng)	M283	Qin Ca. 221-207 BC	Tibia	Female	Adult	0.4	-8.8	10.0	21.6	7.7	3.3	Unknown	1 bronze vessel
Liyi (Xinfeng)	M284	Qin Ca. 221-207 BC	Humerus	Male	35-39	0.3	-7.8	10.0	26.7	9.6	3.2	Unknown	1 bronze vessel
Liyi (Xinfeng)	M288	Qin Ca. 221-207 BC	Tibia	Male	>60	0.7	-8.5	10.7	23.9	8.5	3.3	Unknown	1 common pottery
Liyi (Xinfeng)	M290	Qin Ca. 221-207 BC	Humerus	Male	>60	0.0	-8.1	11.5	42.1	14.6	3.4	Unknown	None
Liyi (Xinfeng)	M292	Qin Ca. 221-207 BC	Femur	Male	Adult	0.5	-7.9	10.3	34.8	12.4	3.3	Unknown	None
Liyi (Xinfeng)	M291	Qin Ca. 221-207 BC	Tibia	?	?	0.6	-9.4	9.7	10.3	3.6	3.4	Unknown	Unknown
Liyi (Xinfeng)	M293	Qin Ca. 221-207 BC	Tibia	Male	25	0.4	-8.0	10.3	32.6	11.6	3.3	Unknown	None
Liyi (Xinfeng)	M302	Qin Ca. 221-207 BC	Femur	Female	40	0.3	-9.1	10.0	18.0	6.2	3.4	Unknown	None
Liyi (Xinfeng)	M305	Qin Ca. 221-207 BC	Tibia	Male	>60	0.3	-7.8	10.6	37.9	13.6	3.3	Unknown	None
Liyi (Xinfeng)	M309	Qin Ca. 221-207 BC	Rib	Male	>60	1.1	-8.0	10.4	41.4	15	3.2	Unknown	1 bronze vessel
Liyi (Xinfeng)	M314	Qin Ca. 221-207 BC	Tibia	Female	25-30	0.6	-9.3	11.2	35.2	12.6	3.3	Unknown	2 common pottery, 1 bronze vessel, 1 silver object
Liyi (Xinfeng)	M325	Qin Ca. 221-207 BC	Humerus	Male	30	0.3	-9.9	10.0	24.5	8.6	3.3	Unknown	4 common pottery
Liyi (Xinfeng)	M326	Qin Ca. 221-207 BC	Tibia	Male	50	0.1	-9.7	10.3	25.1	8.5	3.5	Unknown	6 common pottery
Liyi (Xinfeng)	M331	Qin Ca. 221-207 BC	Tibia	Male	45-50	0.8	-8.1	10.3	28.5	10.3	3.2	Unknown	1 bronze vessel
Liyi (Xinfeng)	M334	Qin Ca. 221-207 BC	Femur	Female	20	0.2	-8.9	10.4	37.3	12.9	3.4	Unknown	1 bronze vessel
Liyi (Xinfeng)	M335	Qin Ca. 221-207 BC	Femur	Female	50	0.2	-9.3	10.4	19.5	6.7	3.4	Unknown	1 bronze vessel

Liyi (Xinfeng)	M337	Qin Ca. 221-207 BC	Tibia	?	?	0.1	-9.4	9.9	31.2	10.7	3.4	Unknown	None
Liyi (Xinfeng)	M338	Qin Ca. 221-207 BC	Tibia	Male	50	1.5	-8.8	10.3	43.2	15.5	3.3	Unknown	None
Liyi (Xinfeng)	M339	Qin Ca. 221-207 BC	Tibia	Male	25-30	0.4	-8.6	10.0	24.0	8.4	3.3	Unknown	None
Liyi (Xinfeng)	M341	Qin Ca. 221-207 BC	Tibia	Male	20-25	0.6	-8.4	10.0	24.5	8.7	3.3	Unknown	None
Liyi (Xinfeng)	M342	Qin Ca. 221-207 BC	Tibia	?	?	0.2	-8.5	9.5	18.2	6.3	3.4	Unknown	Unknown
Liyi (Xinfeng)	M344	Qin Ca. 221-207 BC	Femur	Female	40	0.2	-10.3	9.6	25.8	8.3	3.7	Unknown	1 bronze vessel
Liyi (Xinfeng)	M346	Qin Ca. 221-207 BC	Femur	Male	50	1.1	-10.2	9.5	31.3	11.3	3.2	Unknown	1 bronze vessel
Liyi (Xinfeng)	M349	Qin Ca. 221-207 BC	Tibia	Male	50-55	0.3	-7.6	10.5	37.8	13.1	3.4	Unknown	1 bronze vessel
Liyi (Xinfeng)	M355	Qin Ca. 221-207 BC	Tibia	Female	18-19	0.1	-9.6	10.6	39.6	13.6	3.4	Unknown	1 iron object
Liyi (Xinfeng)	M444	Qin Ca. 221-207 BC	Tibia	Female	45-50	0.2	-8.0	9.9	25.2	8.9	3.3	Unknown	None
Liyi (Xinfeng)	M445	Qin Ca. 221-207 BC	Tibia	Male	45	1.1	-8.1	10.8	32.5	11.8	3.2	Unknown	None
Liyi (Xinfeng)	M453	Qin Ca. 221-207 BC	Humerus	Male	45-50	0.2	-8.1	10.6	34.7	12.4	3.3	Unknown	1 iron object
Liyi (Xinfeng)	M454	Qin Ca. 221-207 BC	Femur	Female	45-50	0.7	-8.0	10.9	37.6	13.7	3.2	Unknown	3 common pottery, 1 bronze vessel
Liyi (Xinfeng)	M455	Qin Ca. 221-207 BC	Tibia	?	?	0.7	-8.3	11.3	37.7	13.9	3.2	Unknown	None
Liyi (Xinfeng)	M458	Qin Ca. 221-207 BC	Humerus	?	?	0.3	-7.5	10.5	30.7	11.1	3.2	Unknown	1 iron object
Liyi (Xinfeng)	M459	Qin Ca. 221-207 BC	Tibia	?	?	0.8	-9.6	10.3	31.0	11.2	3.2	Unknown	1 bronze vessel
Liyi (Xinfeng)	M465	Qin Ca. 221-207 BC	Humerus	?	?	0.3	-9.1	9.4	34.3	12.7	3.1	Unknown	None
Liyi (Xinfeng)	M469	Qin Ca. 221-207 BC	Femur	Male	Adult	0.5	-9.1	10.1	30.2	11.1	3.2	Unknown	1 bronze vessel
Liyi (Xinfeng)	M477	Qin Ca. 221-207 BC	Tibia	?	?	0.9	-7.8	11.4	31.4	10.7	3.2	Unknown	None
Liyi (Xinfeng)	M480	Qin Ca. 221-207 BC	Femur	Male	Adult	1.3	-7.4	10.5	37.4	13.8	3.2	Unknown	None

Liyi (Xinfeng)	M484	Qin Ca. 221-207 BC	Tibia	Male	45-50	0.7	-7.2	10.2	41.6	15.4	3.2	Unknown	None
Liyi (Xinfeng)	M486	Qin Ca. 221-207 BC	Rib	Male	40-44	0.6	-7.6	10.5	31.2	11.3	3.2	Unknown	None
Liyi (Xinfeng)	M489	Qin Ca. 221-207 BC	Tibia	?	?	0.4	-9.2	10.4	35.8	12.9	3.2	Unknown	None
Liyi (Xinfeng)	M491	Qin Ca. 221-207 BC	Humerus	?	?	0.5	-7.6	10.4	34.9	12.8	3.2	Unknown	None
Liyi (Xinfeng)	M518	Qin Ca. 221-207 BC	Femur	Female	>60	0.4	-8.5	10.7	40.2	14.7	3.2	Unknown	1 bronze vessel
Liyi (Xinfeng)	M519	Qin Ca. 221-207 BC	Rib	Female	45-50	0.2	-9.2	11.3	37.3	13.4	3.3	Unknown	1 bronze vessel
Liyi (Xinfeng)	M532	Qin Ca. 221-207 BC	Femur	Female	>60	0.5	-8.5	10.0	35.2	12.8	3.2	Unknown	1 common pottery
Liyi (Xinfeng)	M540	Qin Ca. 221-207 BC	Humerus	Female	40	0.9	-8.9	10.9	32.8	11.9	3.2	Unknown	1 bronze vessel
Liyi (Xinfeng)	M542	Qin Ca. 221-207 BC	Tibia	Female	Adult	0.2	-8.0	10.0	33.6	11.9	3.3	Unknown	None
Liyi (Xinfeng)	M554	Qin Ca. 221-207 BC	Tibia	Female	50	0.8	-8.4	10.5	37.3	13.3	3.3	Unknown	None
Liyi (Xinfeng)	M561	Qin Ca. 221-207 BC	Femur	Female	>60	1.0	-7.3	10.7	32.7	11.9	3.2	Unknown	None
Liyi (Xinfeng)	M564	Qin Ca. 221-207 BC	Tibia	Female	Adult	0.6	-9.0	10.6	36.6	12.8	3.3	Unknown	1 iron object
Liyi (Xinfeng)	M566	Qin Ca. 221-207 BC	Humerus	Female	>60	1.7	-8.4	10.8	38.5	13.9	3.2	Unknown	3 common pottery
Liyi (Xinfeng)	M583	Qin Ca. 221-207 BC	Rib	Female	Adult	0.2	-8.3	9.7	23.5	8.5	3.2	Unknown	1 bronze vessel
Liyi (Xinfeng)	M572	Qin Ca. 221-207 BC	Tibia	?	?	1.4	-8.7	10.8	40.5	14.7	3.2	Unknown	1 common pottery
Liyi (Xinfeng)	M575	Qin Ca. 221-207 BC	Femur	Male	25-30	0.6	-9.5	10.4	38.0	13.6	3.3	Unknown	2 common pottery
Liyi (Xinfeng)	M586	Qin Ca. 221-207 BC	Femur	Female	Adult	0.5	-7.7	10.7	39.1	13.9	3.3	Unknown	4 common pottery
Liyi (Xinfeng)	M588	Qin Ca. 221-207 BC	Tibia	Male	40-45	0.4	-8.6	10.6	39.9	14.2	3.3	Unknown	1 iron object
Liyi (Xinfeng)	M590	Qin Ca. 221-207 BC	Femur	Male	>60	0.6	-9.2	9.8	36.2	13.1	3.2	Unknown	1 bronze vessel
Liyi (Xinfeng)	M591	Qin Ca. 221-207 BC	Tibia	?	?	0.3	-8.0	9.9	24.9	8.9	3.3	Unknown	None

Liyi (Xinfeng)	M605	Qin Ca. 221-207 BC	Tibia	?	?	0.8	-8.2	10.5	27.9	10.1	3.2	Unknown	None
Liyi (Xinfeng)	M641	Qin Ca. 221-207 BC	Femur	?	?	0.4	-8.4	10.7	36.2	12.9	3.3	Unknown	None
Liyi (Xinfeng)	M678	Qin Ca. 221-207 BC	Tibia	?	?	1.2	-8.1	11.6	40.7	14.7	3.2	Unknown	14 common pottery, 4 bronze vessels
Liyi (Xinfeng)	M701	Qin Ca. 221-207 BC	Tibia	?	?	0.7	-9.3	10.7	39.0	14.0	3.3	Unknown	None
Liyi (Xinfeng)	M704	Qin Ca. 221-207 BC	Femur	?	?	1.4	-8.2	11.1	38.3	13.7	3.3	Unknown	6 common pottery
Liyi (Xinfeng)	M709	Qin Ca. 221-207 BC	Humerus	?	?	0.8	-8.2	11.4	38.4	13.4	3.3	Unknown	6 common pottery
Liyi (Xinfeng)	M714	Qin Ca. 221-207 BC	Tibia	?	?	0.0	-9.1	10.4	37.0	12.9	3.4	Unknown	None
Liyi (Xinfeng)	M715	Qin Ca. 221-207 BC	Femur	?	?	0.2	-9.1	11.0	35.7	12.8	3.3	Unknown	None
Liyi (Xinfeng)	M718	Qin Ca. 221-207 BC	Rib	?	?	0.8	-8.6	10.7	28.1	10.0	3.3	Unknown	3 common pottery
Liyi (Wanli)	M3	Qin Ca. 221-207 BC	Humerus	?	?	0.9	-7.9	10.7	42.4	15.0	3.3	Unknown	1 bronze belt hook 7 common pottery
Liyi (Wanli)	M4	Qin Ca. 221-207 BC	Tibia	Male	22-24	0.5	-8.6	10.3	42.1	15.4	3.2	Unknown	1 bronze mirror 1 common pottery
Liyi (Wanli)	M5	Qin Ca. 221-207 BC	Tibia	Female	40-44	0.3	-8.1	11.3	41.2	14.3	3.4	Unknown	1 jade quadrate stamp
Liyi (Wanli)	M6	Qin Ca. 221-207 BC	Tibia	Female	30-35	0.2	-8.5	9.2	26.2	9.4	3.3	Unknown	None
Liyi (Wanli)	M7	Qin Ca. 221-207 BC	Humerus	Female	30-35	0.2	-8.1	10.4	27.3	9.6	3.3	Unknown	1 bronze loop 1 iron belt hook 1 common pottery
Liyi (Wanli)	M9	Qin Ca. 221-207 BC	Tibia	Male	30-35	0.6	-8.4	9.7	40.7	14.9	3.2	Unknown	None
Liyi (Wanli)	M10	Qin Ca. 221-207 BC	Tibia	Female	30-35	0.4	-8.4	10.4	39.5	14.3	3.2	Unknown	None
Liyi (Wanli)	M12	Qin Ca. 221-207 BC	Humerus	Female	35-40	0.3	-8.1	10.7	38.6	14.0	3.2	Unknown	1 bronze belt hook 3 common pottery
Liyi (Wanli)	M14	Qin Ca. 221-	Humerus	?	35	0.6	-8.8	10.7	34.0	11.8	3.4	Unknown	None

		207 BC											
Liyi (Wanli)	M17	Qin Ca. 221-207 BC	Tibia	Female	Adult	0.3	-9.1	10.4	42.3	14.7	3.3	Unknown	2 checker pieces made of pottery
Liyi (Wanli)	M18	Qin Ca. 221-207 BC	Tibia	?	?	0.4	-8.9	10.3	34.6	12.1	3.3	Unknown	2 common pottery
Liyi (Wanli)	M19	Qin Ca. 221-207 BC	Tibia	Male	35-39	0.3	-8.3	10.4	40.9	14.8	3.2	Unknown	None
Liyi (Wanli)	M20	Qin Ca. 221-207 BC	Rib	Female	40-45	0.6	-9.2	10.6	31.7	10.6	3.5	Unknown	None
Liyi (Wanli)	M22	Qin Ca. 221-207 BC	Femur	Female	50-55	0.7	-8.4	9.9	42.4	15.5	3.2	Unknown	None
Liyi (Wanli)	M23	Qin Ca. 221-207 BC	Tibia	Female	40-45	0.7	-7.8	10.2	42.5	15.5	3.2	Unknown	3 shells
Liyi (Wanli)	M24	Qin Ca. 221-207 BC	Humerus	?	30	0.5	-8.1	10.5	40.2	14.4	3.3	Unknown	None
Liyi (Wanli)	M26	Qin Ca. 221-207 BC	Rib	Male	29-30	0.1	-8.5	9.3	35.6	12.8	3.2	Unknown	2 jade objects 1 pottery jar
Liyi (Wanli)	M27	Qin Ca. 221-207 BC	Humerus	Male	40-42	1.1	-8.3	10.8	42.5	15.7	3.2	Unknown	None
Liyi (Wanli)	M29	Qin Ca. 221-207 BC	Femur	Female	45-50	0.6	-8.1	9.9	41.9	15.3	3.2	Unknown	1 jade loop 4 common pottery
Liyi (Wanli)	M33	Qin Ca. 221-207 BC	Tibia	Female	40-44	0.2	-8.7	8.9	38.9	13.7	3.3	Unknown	None
Liyi (Wanli)	M36	Qin Ca. 221-207 BC	Humerus	Female	Adult	0.7	-8.2	10.2	41.4	14.9	3.2	Unknown	3 common pottery
Liyi (Wanli)	M37	Qin Ca. 221-207 BC	Tibia	Male	24-26	1.5	-7.7	10.7	40.5	14.8	3.2	Unknown	4 common pottery
Liyi (Wanli)	M38	Qin Ca. 221-207 BC	Rib	?	35	0.8	-8.2	9.8	42.5	15.4	3.2	Unknown	5 common pottery
Liyi (Wanli)	M42	Qin Ca. 221-207 BC	Tibia	Female	35-40	0.3	-7.5	10.9	31.4	11.0	3.3	Unknown	1 bronze belt hook 2 common pottery
Liyi (Wanli)	M45	Qin Ca. 221-207 BC	Rib	?	?	0.4	-8.3	10.6	42.5	15.5	3.2	Unknown	3 jade objects 1 bronze belt hook 3 common pottery
Liyi (Wanli)	M47	Qin Ca. 221-207 BC	Tibia	Male	31-34	0.4	-8.0	9.9	38.2	13.9	3.2	Unknown	None
Liyi (Wanli)	M48	Qin Ca. 221-207 BC	Humerus	Male	42	0.3	-8.2	10.6	33.2	11.9	3.2	Unknown	1 bronze mirror 3 common

													pottery
Liyi (Wanli)	M51	Qin Ca. 221-207 BC	Rib	Male	35-39	0.8	-8.1	10.7	39.4	14.3	3.2	Unknown	4 common pottery
Liyi (Wanli)	M52	Qin Ca. 221-207 BC	Tibia	Female	36-40	0.3	-8.6	10.4	36.9	13.2	3.3	Unknown	2 common pottery
Liyi (Wanli)	M53	Qin Ca. 221-207 BC	Tibia	Male	31-34	1.0	-8.8	9.3	42.6	15.9	3.1	Unknown	1 bronze mirror 4 common pottery
Liyi (Wanli)	M54	Qin Ca. 221-207 BC	Femur	Male	40-44	0.5	-7.6	10.7	38.8	14.3	3.2	Unknown	9 common potter
Liyi (Wanli)	M55	Qin Ca. 221-207 BC	Tibia	Female	35	0.5	-7.9	9.6	42.3	15.0	3.3	Unknown	1 jade hair clasp 1 bone hair clasp
Liyi (Wanli)	M57	Qin Ca. 221-207 BC	Rib	Male	40-44	1.1	-7.9	11.0	43.0	15.7	3.2	Unknown	1 bronze mirror 4 common pottery
Liyi (Wanli)	M58	Qin Ca. 221-207 BC	Femur	Male	30-35	0.5	-9.0	10.3	42.4	15.0	3.3	Unknown	2 painted pottery 4 common pottery
Liyi (Wanli)	M59	Qin Ca. 221-207 BC	Humerus	Female	50	0.5	-8.8	9.8	42.4	15.5	3.2	Unknown	3 common pottery
Liyi (Wanli)	M62	Qin Ca. 221-207 BC	Tibia	Female	>60	3.2	-8.4	11.0	42.8	15.8	3.2	Unknown	None
Liyi (Wanli)	M72	Qin Ca. 221-207 BC	Humerus	?	?	2.0	-7.5	10.2	43.0	15.77	3.2	Unknown	1 bronze mirror 1 bronze loop 1 bronze spoon 2 iron knives 2 painted pottery 4 common pottery
Liyi (Wanli)	M74	Qin Ca. 221-207 BC	Tibia	Female	35-39	2.3	-8.7	10.5	42.2	15.56	3.2	Unknown	1 bronze mirror 1 common pottery
Liyi (Wanli)	M83	Qin Ca. 221-207 BC	Tibia	Female	25	0.3	-13.8	9.7	41.4	14.80	3.3	Unknown	1 bronze mirror 1 lead object 6 common pottery
Liyi (Wanli)	M84	Qin Ca. 221-207 BC	Humerus	Male	40-45	0.7	-9.0	10.8	49.1	16.69	3.4	Unknown	4 common pottery
Liyi (Wanli)	M86	Qin Ca. 221-207 BC	Femur	Female	40-45	0.1	-13.1	8.6	40.7	14.49	3.3	Unknown	5 common pottery

Liyi (Wanli)	M87	Qin Ca. 221-207 BC	Tibia	Male	31-34	0.2	-9.8	9.9	51.6	18.74	3.2	Unknown	1 iron belt hook
Liyi (Wanli)	M88	Qin Ca. 221-207 BC	Femur	Male	31-34	0.3	-8.9	9.8	43.9	15.56	3.3	Unknown	1 bronze belt hook 1 bronze loop 1 iron object 4 common pottery
Liyi (Wanli)	M91	Qin Ca. 221-207 BC	Tibia	Female	>60	0.2	-7.3	10.1	51.7	18.45	3.3	Unknown	1 common pottery
Liyi (Wanli)	M93	Qin Ca. 221-207 BC	Humerus	Female	45-50	0.4	-8.9	10.2	49.4	17.53	3.3	Unknown	None
Liyi (Wanli)	M94	Qin Ca. 221-207 BC	Humerus	Male	31-34	0.2	-7.9	10.5	48.8	17.25	3.3	Unknown	2 common pottery
Liyi (Wanli)	M97	Qin Ca. 221-207 BC	Humerus	Female	40-44	0.1	-7.0	12.0	50.5	17.79	3.3	Unknown	1 bronze belt hook
Liyi (Wanli)	M104	Qin Ca. 221-207 BC	Rib	?	?	0.5	-7.6	10.0	47.5	16.69	3.3	Unknown	2 common pottery
Liyi (Wanli)	M114	Qin Ca. 221-207 BC	Tibia	Female	40-45	0.1	-7.5	10.1	36.1	12.92	3.3	Unknown	None
Liyi (Wanli)	M116	Qin Ca. 221-207 BC	Tibia	Male	>60	0.5	-7.8	10.9	37.6	13.42	3.3	Unknown	1 bronze belt hook 1 iron belt hook 1 iron knife
Liyi (Wanli)	M25	Qin Ca. 221-207 BC	Tibia	Male	22-23	0.2	-11.3	10.0	48.2	17.13	3.3	Unknown	4 common pottery
Samples below failed to produce collagen													
Shanren	M89	Qin Ca. 221-207 BC	Rib	Male	35-40	--	--	--	--	--	--	Unknown	None
Shanren	M98	Qin Ca. 221-207 BC	Rib	Male	34-35	--	--	--	--	--	--	Impacted tooth	None
Shanren	M105	Qin Ca. 221-207 BC	Tibia	Male	25	--	--	--	--	--	--	Periapical abscess	None
Shanren	M106	Qin Ca. 221-207 BC	Rib	Male	25	--	--	--	--	--	--	Unknown	None
Shanren	M110	Qin Ca. 221-207 BC	Tibia	Male	30-35	--	--	--	--	--	--	Periodontitis, Dental caries	None
Liyi (Xinfeng)	M44	Qin Ca. 221-207 BC	Humerus	Male	60	--	--	--	--	--	--	Unknown	4 common pottery
Liyi (Xinfeng)	M174	Qin Ca. 221-207 BC	Humerus	Female	41-50	--	--	--	--	--	--	Unknown	5 common pottery

Liyi (Xinfeng)	M84	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	2 bronze vessels
Liyi (Xinfeng)	M85	Qin Ca. 221-207 BC	Humerus	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M91	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M93	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M112	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M151	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M178	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M286	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M304	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M307	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M310	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M318	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M328	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M336	Qin Ca. 221-207 BC	Humerus	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M348	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M352	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M353	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M440	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M442	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M461	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown

Liyi (Xinfeng)	M472	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M473	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M479	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M480	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M490	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M492	Qin Ca. 221-207 BC	Rib	Female	50	--	--	--	--	--	--	Unknown	1 bronze vessel
Liyi (Xinfeng)	M493	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M495	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M499	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M500	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M505	Qin Ca. 221-207 BC	Humerus	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M510	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M514	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M516	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M517	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M520	Qin Ca. 221-207 BC	Humerus	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M521	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M529	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M530	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M533	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown

Liyi (Xinfeng)	M535	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M536	Qin Ca. 221-207 BC	Humerus	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M537	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M538	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M541	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M543	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M544	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M545	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M547	Qin Ca. 221-207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M549	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M551	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M557	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M558	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M569	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M569	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M573	Qin Ca. 221-207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M577	Qin Ca. 221-207 BC	Humerus	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M584	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M592	Qin Ca. 221-207 BC	Humerus	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M592	Qin Ca. 221-207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown

Liyi (Xinfeng)	M600	Qin Ca. 221- 207 BC	Rib	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M603	Qin Ca. 221- 207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M634	Qin Ca. 221- 207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M635	Qin Ca. 221- 207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M649	Qin Ca. 221- 207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M665	Qin Ca. 221- 207 BC	Femur	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M668	Qin Ca. 221- 207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M710	Qin Ca. 221- 207 BC	Tibia	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Xinfeng)	M706	Qin Ca. 221- 207 BC	Humerus	?	?	--	--	--	--	--	--	Unknown	Unknown
Liyi (Wanli)	M43	Qin Ca. 221- 207 BC	Tibia	Male	24-26	--	--	--	--	--	--	Unknown	3 common potter
Liyi (Wanli)	M64	Qin Ca. 221- 207 BC	Rib	Female	Adult	--	--	--	--	--	--	Unknown	1 bronze mirror 2 shell 2 bead 1 lacquer ware 7 common pottery
Liyi (Wanli)	M89	Qin Ca. 221- 207 BC	Tibia	Male	40-44	--	--	--	--	--	--	Unknown	None
Liyi (Wanli)	M90	Qin Ca. 221- 207 BC	Rib	Female	42	--	--	--	--	--	--	Unknown	None
Liyi (Wanli)	M96	Qin Ca. 221- 207 BC	Femur	?	Adult	--	--	--	--	--	--	Unknown	1 bronze belt hook
Liyi (Wanli)	M112	Qin Ca. 221- 207 BC	Tibia	Female	30	--	--	--	--	--	--	Unknown	1 bronze belt hook 2 common pottery

CHAPTER 7 Conclusions and Future Work

7.1 Conclusions

The goals and research topics outlined in Chapter 1 have been investigated and successfully completed as a result of this thesis research. In particular, this thesis represents one of the largest and most detailed investigations of paleodiet in China using the technique of stable isotope ratio analysis. This thesis focused on time periods and cultures that were previously underrepresented, in the literature such as the early Bronze/Iron Ages to the Qin Dynasty (221-206 BC). Further, this thesis found new evidence concerning dietary patterns, social stratification (or lack thereof), animal husbandry practices and human mobility during these formative pre-Qin Empire periods. The key findings and their importance in terms of the research questions discussed in Chapter 1 are summarized below.

7.2 Nancheng

At the Proto-Shang site of Nancheng, my research was focused on three main topics: Reconstructing the human diet and animal husbandry patterns to better understand the type of animal protein consumed; examine if different dietary patterns can be linked to sex, age and burial direction/position in the population and to determine if dietary differences existed based on perceived social status, as inferred from the type of grave goods recovered.

In terms of the first research question, my thesis found that the nearly all of the individuals studied had a relatively homogenous diet that was exclusively focused on C₄ resources (millets). Only a single individual (M70) consumed a diet that was a mixture of C₃/C₄ resources. In contrast to the archaeological evidence (different burial position and orientation), individual M70 was determined to most likely not have been a migrant based on the $\delta^{34}\text{S}$ result, which was similar to the general population and domestic animals at the site. This example highlights the important information that can be revealed as a result of using $\delta^{34}\text{S}$ measurements on Chinese skeletal collections. In addition, it was found that the Nancheng population had a diet that was predominately based on

pigs, cattle and possibly dogs. An interesting and important finding was that the sheep/goats were not being consumed in significant amounts by the humans, and were thus likely kept for their secondary products such as wool. This pattern of sheep/goat animal husbandry is similar to the findings at Liuzhuang as well as other sites from this period in north China and may reflect a general pattern where sheep/goats were prized and raised nearly exclusively for their wool production.

At Nancheng, significant isotopic patterns directly related to sex, age and burial direction/position were not observed, but when age and sex were compared together, males older than 40 years had significantly lower $\delta^{13}\text{C}$ values compared to the males below the age of 40 years. This finding could be related to the possible elevated status of older males in this Proto-Shang community or reflect labor divisions between younger and older males, but more research on this topic is necessary in the future. In addition, individuals buried with more or higher quality grave goods were not found to have different diets compared to individuals buried with fewer or common grave goods. Thus, it appears that the social stratification, which is prevalent during later periods (Shang and Zhou Dynasties), is not present at the Nancheng site, and that in general, the entire community was eating a similar and homogenous diet.

7.3 Xishan

At the Late Western Zhou to Warring States Period site of Xishan the following research questions were investigated: were the human diet and animal husbandry practices related to nomadic pastoral activities, agriculture or a mixture of both practices?; did individuals with more or higher quality grave goods have different diets?; were there dietary differences related to status differences between tomb owners and sacrificial victims?; and were there dietary differences between males and females?

The isotopic results of this thesis determined that millet was a significant dietary resource for the Xishan population, but that the individual diet was diverse and spanned the range of nearly complete C_3 to C_4 diets. Interestingly, a linear trend ($R^2 = 0.62$) was discovered in the human $\delta^{13}\text{C}$

and $\delta^{15}\text{N}$ values which paralleled the isotopic results of the animals at the site. However, most of the humans plot with or were only slightly elevated in $\delta^{15}\text{N}$ compared to the animals. Surprisingly, this indicates that these wild and domestic animals were not regularly consumed by the humans but likely used for their labor, secondary products or sacrificial importance. Thus, my thesis work supports the views of the archaeologists and excavators, and indicates that the early Qin were a settled rather than a nomadic/pastoral based society.

At Xishan, high status individuals (based on grave goods) were found to have significantly higher $\delta^{15}\text{N}$ results compared to the low or middle status individuals, and this seems to reflect more pork consumption in their diets. No definitive differences were found between tomb owners and their sacrificial victims, but I acknowledge that the number of individuals was small and that the collection was not complete so further research on this topic is necessary in the future. However, females were found to have elevated $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values compared to the males. This is evidence that the females consumed a diet with more millet and pork while the males ate diets that were a mixture of C_3/C_4 resources including wild animals. Still, caution is necessary with this interpretation as many of the skeletons could not be identified based on sex.

7.4 Qin Shi Huang Mausoleum

For the humans and animals from the Liyi and Shanren sites, that are associated with the Qin Shi Huang Mausoleum, the following research topics were addressed in this thesis: Reconstruction of the diet of these two population to determine if there were differences between these two groups and reviewing the previously published isotopic literature from north and south China to better understand the diets and geographical origins of the individuals found at the Liyi and Shanren sites.

My thesis research determined that the Liyi workers consumed a diet that was composed of predominately millets and/or domestic animals fed millets. However, the prisoners from Shanren had a significantly different diet that was a mix of C_3 and C_4 foods with possibly less domestic animal protein consumption. Comparison of these results to the previously published research from north and south China suggests that the Shanren individuals may have originated from southern

China. Specifically, these prisoners appear to have originated from the ancient Chu state, located in modern day Hubei Province and parts of Hunan and Anhui Provinces, and this discovery agrees with the historical sources and mtDNA evidence.

7.5 Millet Consumption in Northern China

In this thesis, the isotopic results highlight that the majority of individuals from these three study sites had diets that were predominately based on millet. This supports past archaeological work that millet was the typical dietary preference in much of northern China from the late Neolithic to the Qin Dynasty. In particular, at the Nancheng site, the results agree with both the archaeological and literature evidence that millet was the most dominant grain for human diet or for animal fodder during late Neolithic period. Thus, my thesis work revealed that the Proto-Shang had a similar dietary tradition to the inhabitants of the Central Plains when they migrated from the north of China. At the Xishan site, the results indicate that millet farming was very important to the early Qin population in northwest China during the Western Zhou to Eastern Zhou period. This work supports the view that the early Qin were a more settled and agriculture based society at the Xishan site, rather than a nomadic and pastoral based society. On the Guanzhong Plain, where the Liyi and Shanren sites are located, the isotopic results confirm that millet still occupied an important position as a staple food during the Qin Dynasty, even though alternative crops such as wheat, rice and soybean were readily available during this time. Thus, the four sites studied here demonstrate that millet was still an extremely important component to the diets of the inhabitants of northern China during the early Bronze Age to the Qin Dynasty.

7.6 Choices of Animal Protein in the Human Diets

The isotopic results showed that the populations at these three sites consumed varying amounts of domestic animal protein. At both the Nancheng and Xishan sites, pigs were the dominant source of animal protein, but cattle and likely dogs were also consumed to a lesser extent. However, the isotopic results suggest that other animals such as sheep/goats and deer were not regularly eaten, but most likely used for their secondary products, labor or as sacrificial offerings. Further, the

Nancheng site shows strikingly similar animal husbandry patterns compared to other contemporary sites such as Liuzhuang and Xinzhai, which may reveal a common animal husbandry strategy during the terminal Neolithic or Chalcolithic period in the Central Plains of China. For the Xishan site, the results indicate that the early Qin population adopted and exploited a stockbreeding and animal husbandry regime that was influenced by the pre-existing nomadic populations of the central Gansu region. During the Qin Dynasty, the townspeople at the Liyi site, consumed a significant amount of animal protein, but the lack of faunal remains makes it difficult to comment on the preferred species that were consumed. In contrast, the prisoners from the Shanren site were found to have likely consumed significantly less animal protein from domestic animals and possibly only ate wild game.

7.7 Social Status

When it was possible, links between the isotopic results and: sex, age and social status were investigated at all the sites presented in this thesis. At the Nancheng site, no significant correlations between diet and burial direction/position or social status (based on the type of grave goods) were found. This is possible evidence that dietary social stratification had yet to be established during the transformative Proto-Shang period of China. In contrast, my thesis result showed that high status individuals had significantly elevated $\delta^{15}\text{N}$ results compared to the low or middle status individuals at the later site of Xishan. This might indicate that high status individuals were having more animal protein in their diets compared to the common people. In addition, significant differences in both mean $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values were also found between males and females at Xishan. This suggests that females were consuming a diet that was mainly based on millet and pork while the males had more diverse diets that were a mix of C_3 and C_4 plants and different animals, both wild and domestic. Further, four cases of human sacrifice were analyzed at the Xishan site, and the results indicate that it might be possible to identify the social rank or identity of these individuals. However, due to the very small sample size, caution is needed in the interpretation of these findings. At the Liyi and Shanren sites, isotopic differences related to social class and geography were found. The Liyi individuals were local worker at the Qin Shi Huang Mausoleum whereas the Shanren individuals were prisoners or slaves (buried in a mass grave and

in iron shackles). The large isotopic differences between the two groups suggest that the Shanren individuals were possibly from another part of China (likely the south), and had diets with decreased amount of millet and domestic animal protein. Thus, the large isotopic differences in carbon, between populations of north and south China, make it possible to track the migration of individuals between these two regions. This finding will be of great importance for future isotopic research on Chinese skeletal materials.

7.8 Limitations of this Thesis and Future Research

While this thesis presented some of the largest isotopic studies on Chinese materials to date, there are limitations that can be highlighted and discussed in relation to this current work. The work present here was focused on bone collagen, and tooth enamel apatite and dentine serial sections were not studied. This was due to the fact that it can be very difficult gain access to human remains for isotopic analysis or other archaeological science techniques in China. Many archaeologists, excavators and museum curators are unfamiliar with this type of research in China and are reluctant to provide materials for sampling. I encountered this firsthand when I was trying to obtain materials for this thesis. In particular, teeth are even more difficult to obtain for sampling than bones, and this is one of main reasons why I was not able to sample teeth as part of this thesis. Ideally, it would be beneficial in the future to compare isotopic studies of teeth (apatite and dentine serial sections) with the bone collagen results to create more detailed dietary life histories and mobility patterns for the individuals of these population.

In addition, to the animals that were sampled as part of this thesis, it would be ideal to isotopically analyze plant, bird and fish specimens from these sites. However, this was not possible as these plant and smaller faunal remains were not saved during the excavation process at these sites. This is an unfortunate reality of archaeological research here China where the value of these remains have been overlooked in the past. However, archaeological research and excavation techniques have improved significantly over the past decade and now more attention is being focused on these archaeobotanical and smaller zooarchaeological remains. However, there is still more work to be done about educating the archaeological community about the value of these items, and I hope to be able to sample these remains as part of future isotopic research projects here in China.

One of the most promising areas of future isotopic research for Chinese archaeological collections is that of $\delta^{34}\text{S}$ analysis. While the sulfur results presented for the Nancheng site in chapter 4 of this thesis are some of the first for a Chinese archaeological site, only a small number of humans (n=12) and animals (n= 20) provided enough collagen for analysis. Thus, it would be important to try and do a larger number of $\delta^{34}\text{S}$ measurements at the Nancheng site. In addition, it would be good to isotopically analyze the Xishan remains for sulfur to see if there were also differences related to status and/or sex. At the Liyi and Shanren sites, $\delta^{34}\text{S}$ analysis would be ideal to confirm if the Shanren individuals were originally from the south of China. Thus, the combined analysis of carbon, nitrogen and sulfur isotope ratios would be able to provide important new information about the lives and histories of the Shanren prisoners. Finally, other sites with large collections of human remains that have been analyzed for sex, age and social rank should be examined in China. In particular, it would be important to do a diachronic study of different sites within a region to see when and how social stratification as related to human diet was established. I hope that my work presented in this thesis will encourage these types of new and exciting investigations.

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SUMMARY

Here, the stable isotope ratios of carbon ($\delta^{13}\text{C}$), nitrogen ($\delta^{15}\text{N}$) and sulphur ($\delta^{34}\text{S}$) are measured to examine human diet, social stratification, mobility and animal husbandry practices. Three locations comprising four sites from the Yellow River Valleys of north China are investigated: Nancheng (Hebei Province), Xishan (Gansu Province), Liyi and Shanren (Shaanxi Province), and this work represents one of the largest and most detailed isotopic research projects ever conducted in China.

At the Proto-Shang (ca. 2000-1600 BC) site of Nancheng, the isotopic analysis of humans ($n=83$) and animals ($n=36$) indicates that millet was the dominant grain used for both human food and animal fodder, and that individuals ate varying levels of animal protein, primarily pigs but also cows and possibly dogs. Sheep/goats and deer were not main sources of animal protein in the human diets, and this suggests that these animals were used for their secondary products, labor or as sacrificial offerings. In addition, no social stratification related to diet in this transitional Neolithic to Bronze Age society was found. This indicates that the social stratification of later periods, such as during the Shang and Zhou Dynasties, possibly had yet to be established during this period.

At the Late Western to Early Eastern Zhou period (ca. 700-400 BC) site of Xishan, the isotopic results of the humans ($n=33$) and animals ($n=58$) reveal that millet farming was important to this early Qin population. This finding supports the view that the early Qin people were a more settled and agricultural based society, rather than a nomadic and pastoral based society. Individuals of high status had significantly elevated $\delta^{15}\text{N}$ results compared to the middle or low status individuals, and this is possible evidence that they were having more animal protein in their diets compared to the common people. In addition, significant differences in both mean $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values were also found between females and males. The females consumed a diet mainly based on millet and pork, while the males had more diverse diets that were a mix of C_3 and C_4 plants and different animals, both wild and domestic. Further, sacrificed individuals were analyzed, and the results indicate that it might be possible to identify the social rank or identity of these individuals.

At the Mausoleum complex of the First Emperor of China, Qin Shi Huang, humans from two Qin Dynasty (221-206 BC) sites, Liyi (n=146) and Shanren (n=14) as well as animals (n=9) were isotopically investigated. The Liyi site represents the local workers or craftsmen of the Mausoleum complex, whereas the Shanren individuals were slaves or prisoners who were forced to do hard labor, and were buried in a mass grave. The large isotopic differences between the two sites suggest that the Shanren individuals were possibly from the south of China, and they had diets with decreased amounts of millet and domestic animal protein compared to the Liyi individuals. Thus, the large isotopic differences in carbon, between populations of north vs. south China, make it possible to track the migration of individuals between these two regions.

SAMENVATTING

Deze studie meet de stabiele isotopenverhoudingen van koolstof ($\delta^{13}\text{C}$), stikstof ($\delta^{15}\text{N}$) en zwavel ($\delta^{34}\text{S}$) voor onderzoek van menselijke voeding, sociale stratificatie, mobiliteit en veeteelt praktijken. Drie locaties bestaande uit vier sites in valleien van de Gele Rivier in het noorden van China zijn onderzocht: Nancheng (provincie Hebei), Xishan (provincie Gansu), Liyi en Shanren (provincie Shaanxi). Deze studie is een van de grootste en meest gedetailleerde isotopen-onderzoekprojecten ooit in China uitgevoerd.

Voor de Proto-Shang (ca. 2000-1600 BC) site Nancheng, geeft isotopenanalyse van menselijke ($n = 83$) en dierlijke skeletresten ($n = 36$) aan dat gierst het dominante graan was, gebruikt voor zowel menselijk voedsel als veevoer, en dat individuen verschillende niveaus van dierlijke eiwitten consumeerden, voornamelijk varkens maar ook koeien en mogelijk honden. Schapen / geiten en herten waren geen belangrijke bronnen van dierlijke eiwitten in de menselijke voeding, en dit suggereert dat deze dieren werden gebruikt voor hun secundaire producten, voor werk of als offerdieren. Bovendien zijn er geen dieet-gerelateerde aanwijzingen voor sociale stratificatie gevonden in deze samenleving uit de overgangperiode van het Neolithicum naar de Bronstijd. Dit duidt erop dat de sociale stratificatie van latere periodes, zoals tijdens de Shang en Zhou Dynastieën, tijdens deze Proto-Shang periode mogelijk nog niet aanwezig was.

Voor de Late Western tot Early Eastern Zhou (ca. 700-400 BC) site Xishan geven de isotoop resultaten van mens ($n = 33$) en dier ($n = 58$) aan dat de verbouw van gierst belangrijk was voor deze vroege Qin populatie. Deze bevinding ondersteunt de opvatting dat de vroege Qin populatie een meer sedentaire en op landbouw gebaseerde maatschappij vormde, in plaats van een nomadische en pastorale. Individuen met een hoge status vertonen significant hogere $\delta^{15}\text{N}$ waarden dan midden- of lagere status individuen, een aanwijzing dat ze meer dierlijke eiwitten in hun voeding hadden. Daarnaast zijn er significante verschillen in gemiddelde $\delta^{13}\text{C}$ en $\delta^{15}\text{N}$ waarden tussen vrouwen en mannen. Het dieet van vrouwen was voornamelijk gebaseerd op gierst en varkensvlees, terwijl mannen meer diverse diëten hadden: een mix van C_3 en C_4 planten en verschillende dieren, zowel wilde als gedomesticeerde. Verder werden geofferd individuen geanalyseerd en de resultaten geven aan dat het mogelijk zou kunnen zijn de sociale rang of de

identiteit van deze personen te identificeren.

Van het Mausoleum-complex van de eerste keizer van China, Qin Shi Huang, zijn mensen uit twee Qin-dynastie (221-206 BC) sites, Liyi (n = 146) en Shanren (n = 14), isotopisch onderzocht, alsmede enkele dieren (n = 9). Het assemblage van de Liyi site vertegenwoordigt de lokale arbeiders en ambachtslieden van het mausoleum complex, terwijl de Shanren personen slaven waren, of gevangenen die gedwongen werden om zwaar werk te doen, en werden begraven in een massagraf. De grote isotopische verschillen tussen de twee sites suggereren dat de Shanren individuen mogelijk uit het zuiden van China afkomstig waren, en in hun dieet geringere hoeveelheden gierst en dierlijke eiwitten van gedomesticeerde dieren hadden dan de Liyi individuen. De grote isotopische verschillen in koolstof tussen populaties uit het noorden versus het zuiden van China, maken het mogelijk om de migratie van individuen tussen deze twee regio's te traceren.

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